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ABSTRACT

In this report the National Science Board presents the first results from a newly initiated effort to develop indicators of the state of the scientific enterprise in the Unite States. The ultimate goal of this effort is a set of indices which will reveal the strengths and weaknesses of U.S. science and technology, in terms of the capacity and performance of the enterprise in contributing to national objectives. Indicators in this report deal with facets of the entire scientific endeavor, as well as certain aspects of technology. They range from measures of basic research activity and industrial research and development, through indices of scientific and engineering personnel and institutional capabilities, to indicators of productivity and the U.S. balance of trade in high-technology products. In addition to graphically presenting the indicators, the report also provides results from opinion and attitude surveys of topics related to the state of science. The first of these is a Delphi survey of the judgments and opinions of a wide cross-section of the scientific and technological community, and the second surveys the attitudes of the public toward science and technology. (Author/JR)

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Science Indicators 1972

National Science Board
1973

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Report of the
National Science Board
1973

National Science Board
National Science Foundation

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Letter of Transmittal

January 31, 1973

My Dear Mr. President:

I have the honor of transmitting to you, and through you to the Congress, the Fifth Annual Report of the National Science Board. The Report is submitted in accordance with Section 4(g) of the National Science Foundation Act as amended by Public Law 90-407.

In this Report the National Science Board presents the first results from a newly initiated effort to develop indicators of the state of the science enterprise in the United States. The ultimate goal of this effort is a set of indices which would reveal the strengths and weaknesses of U.S. science and technology, in terms of the capacity and performance of the enterprise in contributing to national objectives. If such indicators can be developed over the coming years, they should assist in improving the allocation and management of resources for science and technology, and in guiding the Nation's research and development along paths most rewarding for our society.

Because of present limitations in data and methodology, the indicators in this Report deal principally with resources—funds, manpower, and equipment—for research and development and the areas to which the resources are directed. The Report presents relatively few measures of the outputs produced from these resources—the scientific advances and technological achievements, and their contributions to the progress and welfare of the Nation. The present paucity of such indices limits the conclusions which can be drawn concerning the quality and effectiveness of our scientific and technological effort.

The Report represents only an initial step toward a system of science indicators. The further development of such indicators is a matter of high priority for future reports in this series.

Respectfully yours,

H. E. Carter

H. E. Carter
Chairman, National Science Board

The Honorable
The President of the United States

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Introduction

The National Science Board is charged by the Congress with providing an annual report of the state of science in the United States.[1] In its first four reports, the Board dealt with selected aspects of this subject, but with this, the fifth report, the Board begins the development of a system of indicators for describing the state of the entire scientific endeavor. These indicators, expanded and refined in the coming years, are intended to measure and monitor U.S. science—to identify strengths and weaknesses of the enterprise and to chart its changing state.

Such indicators, updated annually, should provide an early warning of events and trends which might reduce the capacity of science—and subsequently technology—to meet the needs of the Nation. The indicators should assist also in setting priorities for the enterprise, in allocating resources for its functions, and in guiding it toward needed change and new opportunities.

A system of science indicators which would fulfill these several purposes must include indices of both intrinsic and extrinsic aspects of the enterprise. Intrinsic measures would include the resources used for science; the condition of institutions involved in training, research, and technical innovation; quantity and quality of associated human resources; and advances in science. Extrinsic indices center around the application of scientific knowledge, and the technology it fosters, to the achievement of national goals—in areas such as health, energy, environment, defense, productivity, and foreign trade—and the consequent impacts on that elusive entity, the "quality of life." Measures of these extrinsic aspects are particularly difficult to devise; the translation of science into technology, the diverse applications of the two, and their myriad impacts are all intertwined with innumerable economic and social variables.

The realization of such a system of indicators—or even one which is less comprehensive—will be a difficult and long task, requiring

- investigation of many potential indices,
- expansion of the underlying data base,
- improvement of methods for measuring the impacts of science and technology,
- experience in interpreting the indices, and
- demonstration of their utility.

In view of these problems and uncertainties, the effort to develop indicators is regarded as an experiment—a long-term experiment to determine if a useful system of indices can be devised in the years ahead. A central concept of the experiment is an evolving set of indicators, derived from the continuing exploration, refinement, and testing of prospective indices. The set will be expanded, refined, and updated annually, as new data become available and as the enterprise itself changes. Throughout, the criterion of "usefulness" will be used to judge the value of individual indices, and to gauge the success of the experiment as it unfolds.

Quantitative indicators, no matter how useful, are not a substitute for the experience and judgment of the scientific community. Indices, at their best, can only supplement this experience and judgment. Indeed, the interpretation of indicators—what they mean for the present and future health of the enterprise—requires the judgment of this community.

The Report

Indicators in this report deal with facets of the entire scientific endeavor, as well as certain aspects of technology. They range from measures of basic research activity and industrial R&D, through indices of scientific and engineering personnel and institutional capabilities, to indicators of productivity and the U.S. balance of trade in high-technology products. Such a broad range of indices was included in the initial step of the experiment in order (a) to explore the scope of the effort involved in developing a relatively comprehensive system of indicators, (b) to identify gaps in the data base, and (c) to select specific areas for focused efforts in the future.

While many potential indices were conceived for future development and a number of new concepts and even new data collections were initiated, the actual indicators in the report were based largely on readily available data. As a result, the indices deal principally with resources—funds and personnel—for R&D, the disciplinary and functional areas to which the resources are directed, and the institutions which carry out the teaching and research functions. Relatively few output measures of either an intrinsic or extrinsic nature are presented, because of the limited data available and methodological problems of separating the distinct contributions of science and technology from those of other factors. Furthermore, the few such indicators which are presented (e.g., quantity and quality of scientific publications, patent output, and trade in technical knowledge) are subject to considerable uncertainty as to valid interpretation and significance. These deficiencies limit the conclusions which can be drawn regarding the performance and contributions of the enterprise.

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[1] Section 4(g) of the National Science Foundation Act as amended by Public Law 90-407.

The first five chapters of the report present the initial set of indicators. The indices, wherever possible, are time series, usually extending from the early 1960's through 1972. Indicators are presented in graphical form and numbered so as to correspond with the numerical data tables in Appendix A. Preceding each of these chapters is an "indicator highlights" section which briefly summarizes the major indices presented in the chapter. These sections, it should be noted, often omit important caveats and discussion contained in the full text.

The last two chapters present results from opinion and attitude surveys of topics related to the state of science, which are not amenable to purely quantitative treatment. The first of these is a Delphi survey of the judgments and opinions of a wide cross section of the scientific and technological community; the topics covered include the future role of science and technology in areas of high public concern, impacts of recent R&D funding changes, and basic research and criteria for allocating resources among scientific fields. The second is a survey of attitudes of the public toward science and technology; topics covered in the survey include the public regard for science and technology, their assessment of its impacts, and their desires for its future use in coping with national problems.

The task initiated with this report is ambitious; the present effort clearly represents only a beginning. The reports to follow in this series will aim to improve the concepts, refine the treatment, and expand the scope to include other facets of science and technology.

International Position of U.S. Science and Technology

International Position of U.S. Science and Technology

This chapter compares the position and performance of science and technology in the United States with that of other major R&D-performing nations, through a variety of indicators. These include comparative indices of the level of R&D, in terms of expenditures for such activity and the number of scientists and engineers involved; results of R&D, as measured by the output of scientific reports and patents for new products and processes; and national performance in areas dependent upon science and technology, such as technical knowledge, productivity, and international trade.

International comparisons are confined to general trends and to relative rather than absolute indicators, because of the paucity and limited quality of available information. This applies with particular force to comparisons involving the U.S.S.R. where definitions of R&D and scientific personnel often differ from those of other countries.

Specific indicators must be interpreted with considerable caution. Indices of the level of R&D can be misleading because the costs of such activities, and differences in the productivity and functions of scientists and engineers, cannot yet be equated for the various countries. The output indices of scientific reports and patents reflect only a small part of the total output of science and technology, whereas the last group of indicators—those dealing with technical knowledge, productivity, and international trade—include the effects of many factors, science and technology being only one of them.

INDICATOR HIGHLIGHTS

- The proportion of the gross national product (GNP) spent for research and development (R&D) between 1963-71 declined in the United States, France, and the United Kingdom but increased in the Union of Soviet Socialist Republics (U.S.S.R.), Japan, and West Germany. By 1971, U.S. expenditures for R&D were 2.6 percent of GNP, as compared with an estimated 3.0 percent for the U.S.S.R., approximately 2.0 percent for the United Kingdom and West Germany, and 1.8 percent for both Japan and France.
- The number of scientists and engineeers engaged in R&D per 10,000 population declined in the United States after 1969 but continued to increase in the U.S.S.R., Japan, West Germany, and France, with the result that by 1971 the number per 10,000 population for the U.S.S.R. was 37 as compared with 25 for the United States and Japan, 15 for West Germany, and 12 for France.
- All countries included in the comparisons significantly reduced the proportion of their government R&D expenditures for national defense between 1961 and 1969, with such expenditures in the United States dropping from 65 to 49 percent of total government R&D spending. Increases in the United States and most other countries occurred in the areas of space, community services, and economic development.
- In seven of eight scientific areas studied,[1] the United States produces a larger share of the world's scientific and technical literature than any of the other major developed countries; the U.S. share remained essentially unchanged between 1965-71.
- Literature produced by the United States is more frequently cited than that produced by other countries in all the scientific areas studied, with the exception of systematic biology and mathematics where the United Kingdom stands first.

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[1] The areas were physics and geophysics; chemistry and metallurgy; molecular biology; systematic biology; mathematics; engineering; psychology; and economics.

- The United States had a favorable but declining "patent balance" (patents of United States versus foreign origin awarded in each country) between 1966 and 1970; the decline was due to a reduced number of patents of U.S. origin in France, West Germany, and the United Kingdom, combined with increased U.S. patents of Japanese origin.
- Starting from a higher base, increases in labor productivity in U.S. manufacturing industries between 1960-71 were the lowest of all countries—39 percent—compared with 210 percent for Japan, 86 percent for West Germany, 81 percent for France, and 50 percent for the United Kingdom. Productivity gains in the United States offset increased labor costs until the mid-1960's, but rose less rapidly than such costs during the 1966-71 period.
- The United States had an increasingly favorable position in the sale of "technical know-how"—patents, techniques, formulas, franchises, and manufacturing rights—during 1960-71. Japan was the major purchaser of U.S. "know-how," surpassing all of Western Europe after 1967.
- The favorable U.S. balance of trade in technology-intensive products grew throughout 1960-71 but was increasingly negative in nontechnology-intensive areas.
- Within the technology-intensive areas, products with the fastest rising trade surplus are aircraft, computers, and plastics. Product areas in which the growth of imports exceeds exports include office machinery, chemical elements and compounds, medicinal products, and telecommunication apparatus.
- The favorable trade balance of the United States in high technology products rested primarily on purchases by developing nations (55 percent in 1971) and countries of Western Europe. A deficit balance with Japan, developed in the mid-1960's and continuing to grow through 1971, exists in electrical machinery, scientific and professional instruments, and nonelectrical machinery.

■ The basis chosen for appraisal of U.S. science and technology in this chapter is an international one, where the position of the United States is compared with that of other developed countries, particularly the major R&D-performing OECD (Organisation for Economic Cooperation and Development) member nations.[2] For reasons cited previously, comparisons are usually restricted to measures of relative magnitude and to general trends.

LEVEL OF RESEARCH AND DEVELOPMENT

The principal indicators of the level of a nation's R&D effort are the expenditures and manpower devoted to such activities. The general objectives of such efforts, in turn, are suggested by the specific areas (e.g., defense, space, and economic development) to which these resources are directed.

Expenditures for R&D

Figure 1 presents expenditures for R&D as a percentage of gross national product for the six major R&D-performing countries included in the study. The United States, as well as France and the United Kingdom, show a declining ratio, as compared with increases for the U.S.S.R., Japan, and West Germany. Over the 1963-71 period (the only years for which data are available or can be estimated for all countries), the United States exhibits the largest reductions, the U.S.S.R. and Japan the largest increases.

R&D Manpower

Another indicator of the level of a country's R&D effort is the magnitude of the manpower (scientists and engineers) it devotes to these activities. This indicator should be regarded as only an approximation of the true level of R&D in that it fails to account for certain national differences, such as the designation and training of scientists, engineers, and technicians, and the quality of the research equipment available.

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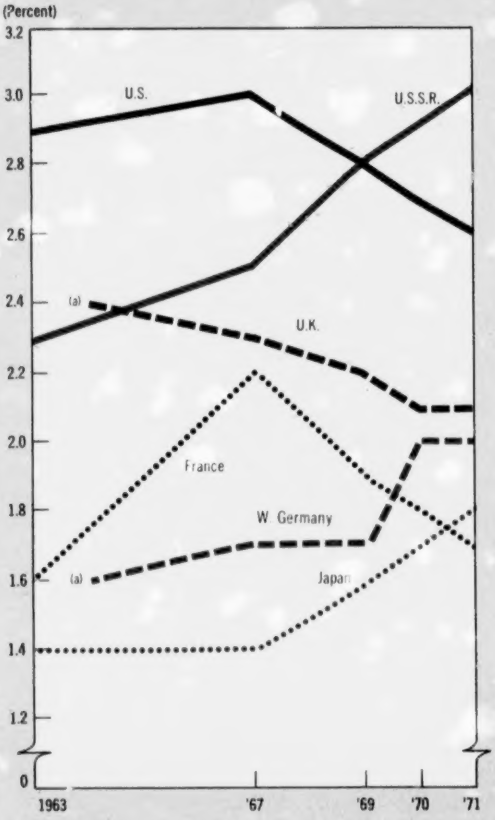
[2] The U.S.S.R. is included in the comparisons wherever the available data permit. Limited data and differences in definitions restrict the comparisons which can be made.

Figure 1

R&D Expenditures as a Percent of Gross National Product, by Country, 1963-71



(a) 1964

SOURCE: Organisation for Economic Cooperation and Development; National Science Foundation estimates for 1970 and 1971; U.S.S.R. estimates by Robert W. Campbell, Univ. of Indiana.

These differences also enter into determining the *effective* R&D level.

The number of scientists and engineers engaged in R&D per 10,000 population in the United States, France, West Germany, Japan, and the U.S.S.R. is shown in figure 2. (Data for the United Kingdom are not available.) Taking the limitations noted above into consideration, these trends indicate that the U.S.S.R. surpassed the United States after 1967 in the proportion of its population employed in R&D, and that Japan had almost reached the same level as the United States by 1971. Moreover, of the five countries compared, only the United States had a declining ratio of scientists and engineers engaged in R&D.

Government-Funded Research & Development

Governments fund R&D in the pursuit of national objectives in various areas, such as national defense, economic development, and space. The distribution of funding among these objectives reflects national priorities whereas significant changes in the distribution often indicate shifts in national concerns. Government expenditures for R&D, however, represent only a part of the total national investment in R&D; expenditures by the private sector must also be taken into account for international comparisons.

The OECD has attempted to classify government expenditures for R&D into the following six areas:

National Defense, encompassing military-oriented R&D as well as space and nuclear energy activities of a military character;

Space Exploration, restricted to space R&D activities of a civil nature;

Nuclear Energy, restricted to nuclear energy R&D activities of a civil nature;

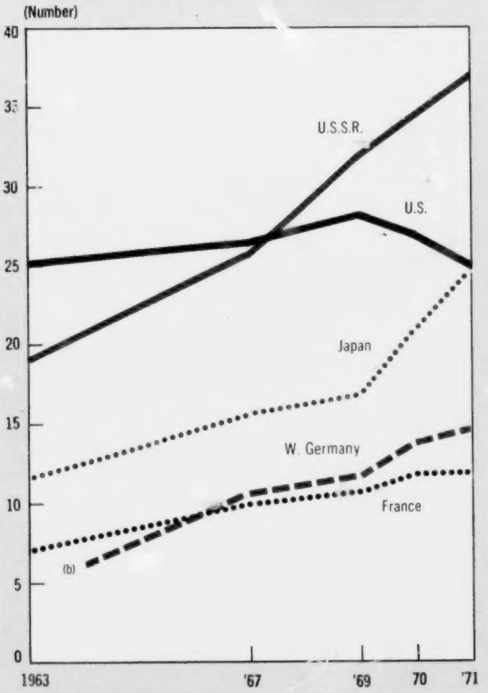
Economic Development, including R&D in agriculture, fishing, and forestry, in mining and manufacturing industries, as well as service sectors such as public works, public transportation, communications, and construction;

Community Services, including R&D in health, the environment, public welfare (education, social services, planning, recreation, and culture), disaster prevention, law and order, meteorology, planning, and statistics;

Advancement of Science, including government-funded research in universities, both separately budgeted research as well as research from the general funds of universities provided by the government.

Figure 2

Scientists and Engineers[a] Engaged in R&D per 10,000 Population, by Country, 1963-71



(a) Includes all scientists and engineers (full-time-equivalent basis).

(b) 1964

SOURCE: Organisation for Economic Cooperation and Development; National Science Foundation estimates for 1970 and 1971; U.S.S.R. estimates by Robert W. Campbell, Univ. of Indiana.

The distribution of total government expenditures for R&D among these areas is shown in figure 3 for the United States, United Kingdom, France, West Germany, and Japan for the years 1961 and 1969. (Data for the U.S.S.R. are not available.)

The chief changes in the United States between the 1961 and 1969 periods were the proportional reductions in R&D expenditures for national defense (down from 65 percent to 49 percent of total expenditures) and increases in the areas of space, community services, and economic development. Relative reductions in defense R&D also occurred in each of the other four countries, while the major increases, although differing from country to country, were in space, economic development, and the advancement of science. (Expenditures for the latter area are difficult to compare from country to country because of different government practices in the funding of university research; some governments provide support for such research through general grants to universities, whereas others—such as the United States—provide much of their support through mission-oriented agencies for specific research projects.)

RESULTS OF RESEARCH AND DEVELOPMENT

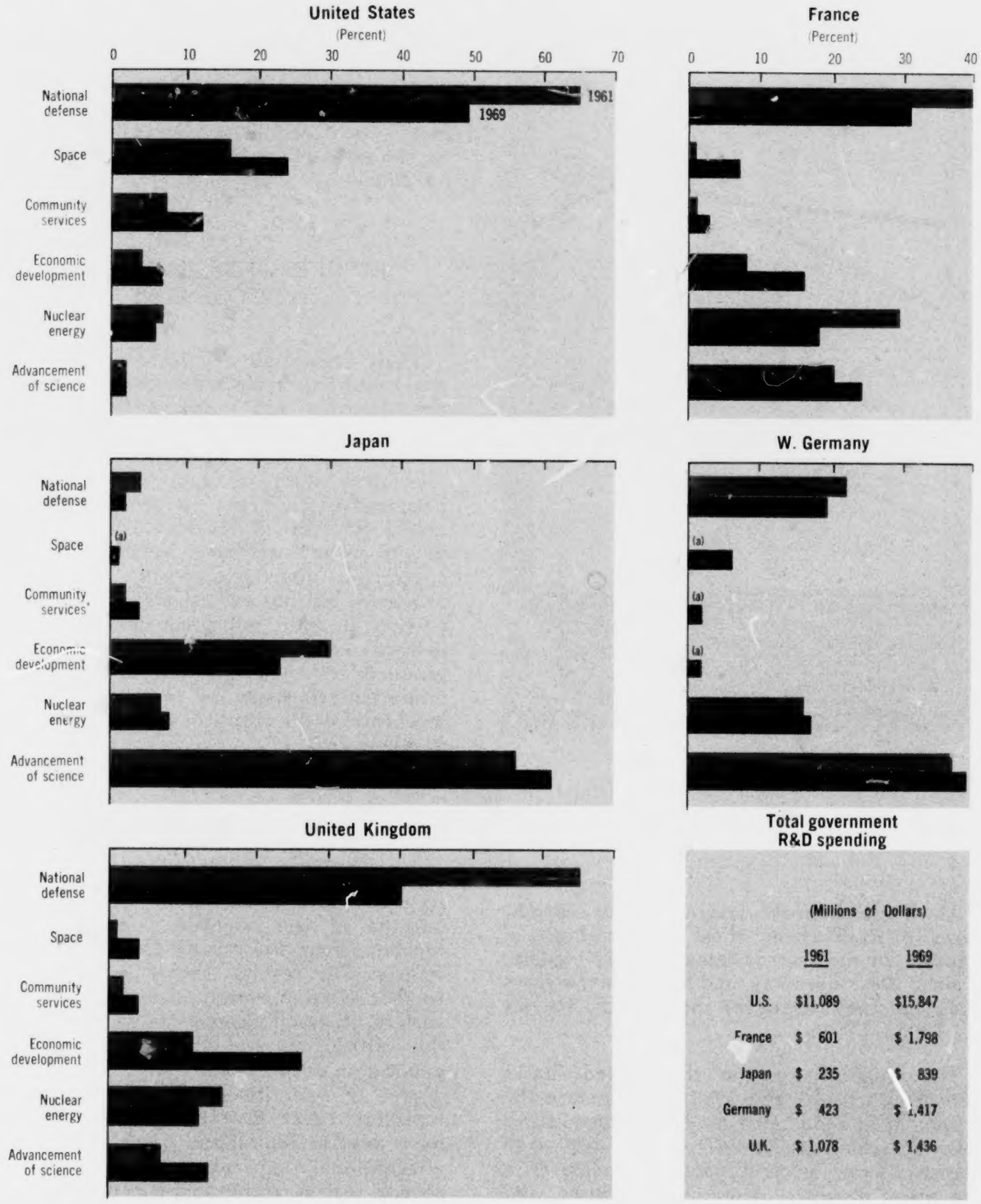
There are certain relatively direct results of R&D which provide indicators for comparing the scientific and technical performance of nations. Primary among these are reports of research published in scientific and technical journals, citations of reports from these journals, and patents for new products and processes. These provide measures of certain aspects of the output of the scientific-technological enterprise. Journal reports are produced primarily, but not exclusively, by the scientific portion of the enterprise as the result of research, both basic and applied, while new products and processes leading to patents are produced principally by industrial firms and inventors as the result of applied research and development.

Scientific and Technical Publications

Research reports published in scientific and technical journals are one of the more tangible outputs of the scientific community. Such reports reflect the results of specific research efforts. The results themselves may lead to further research, or be used many times over in a variety of practical applications. Furthermore, the critical review which usually precedes publication ensures that the reports have some degree of scientific or technical significance. Indicators based on research reports, however, have several limitations for the purpose of international comparisons: the quantity of such reports may be influenced substantially by the national customs regarding the publishing of research papers, by the availability of funds for

Figure 3

Distribution of Government R&D Expenditures Among National Objectives, by Country, 1961 and 1969



(Millions of Dollars)

	1961	1969
U.S.	$11,089	$15,847
France	$ 601	$ 1,798
Japan	$ 235	$ 839
Germany	$ 423	$ 1,417
U.K.	$ 1,078	$ 1,436

(a) Less than 1 percent

SOURCE: Organisation for Economic Co-operation and Development preparing and printing papers, by journal refereeing and publishing policies, etc. These factors provide good reason for caution in interpreting such indicators.

The data presented here are the results of an initial attempt to:

(1) Estimate the proportion of the world's significant research and technical literature (in selected scientific areas) which is produced by the United States and other major countries, and

(2) Assign a figure of merit representing the quality or significance of the literature produced in each area by each country.

The scientific areas and countries encompassed are shown below:

Scientific Areas

Physics and Geophysics
Chemistry and Metallurgy
Molecular Biology
Systematic Biology
Psychology
Economics
Mathematics
Engineering

Countries

France
Japan
United Kingdom
United States
U.S.S.R.
West Germany

National Origins of Literature. Estimates of the distribution of literature among fields and countries were based upon counts of articles, letters, and notes published in some 500 journals covered by the *Science Citation Index* (published by the Institute for Scientific Information, Philadelphia, Pa.), supplemented by data from various abstracting services.[3] The results are presented in figure 4.

The United States has a larger share of the literature in each of the areas (except for chemistry and metallurgy) than any other country. The U.S. share, as well as those of other countries, shows little change over the short period (1965-71) covered by the data.

In the area of physics and geophysics, the United States produces some 40 percent of the literature, as compared with about 15 percent from the U.S.S.R., and between 5 to 8 percent from each of the other four countries. However, in the other physical science area—chemistry and metallurgy—the U.S.S.R. has the largest share with some 29 percent, versus the 24-percent share of the United States, and the 5- to 9-percent share of each of the other four countries.

In molecular biology the United States produces almost one-half the world's literature, with each of the two next largest producers (United Kingdom and France) having shares of only 9 percent. The U.S. share of the systematic biology literature is considerably less, at some 30 percent, than molecular biology, but still exceeds that of any other individual country by a wide margin.

In psychology and economics, literature of U.S. origin represents the largest share. The available data for both areas, however, were more limited and less reliable than data for other areas. In spite of these limitations, the relative position of the United States in each area is believed to be accurately reflected by the data.

In mathematics the United States and U.S.S.R. share the lead as the major literature producers, with the United States having a slightly larger share. The shares of the other four countries range from 4 to 7 percent.

In engineering the United States produces about 50 percent of the world's literature. The next largest producers are the U.S.S.R. with 12 percent, and the United Kingdom with about 10 percent.

Literature Citations. In addition to the purely quantitative aspects, an effort was made to estimate the relative "quality" or "significance" of the literature. The basis for this indicator was the number of citations to the literature

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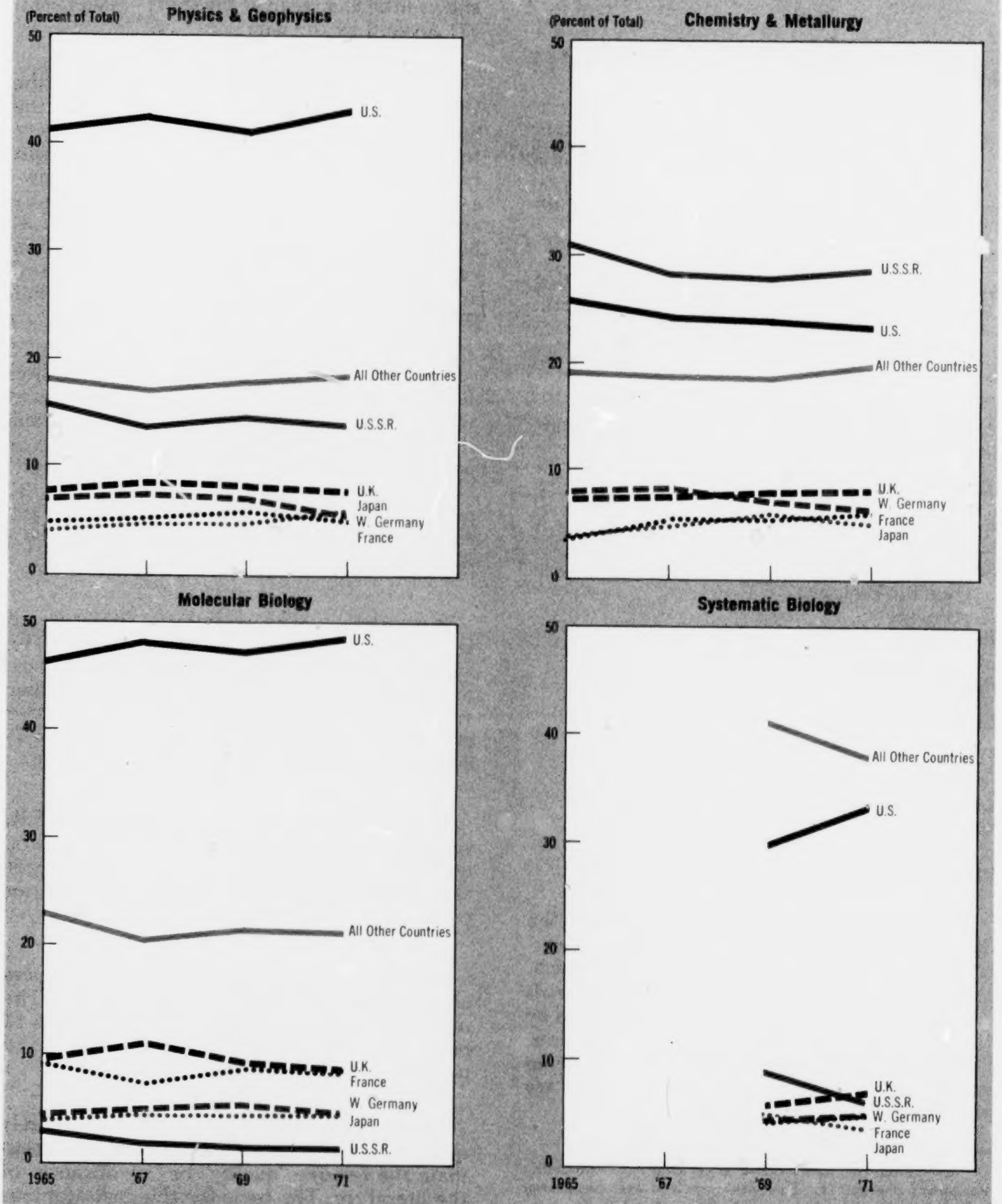
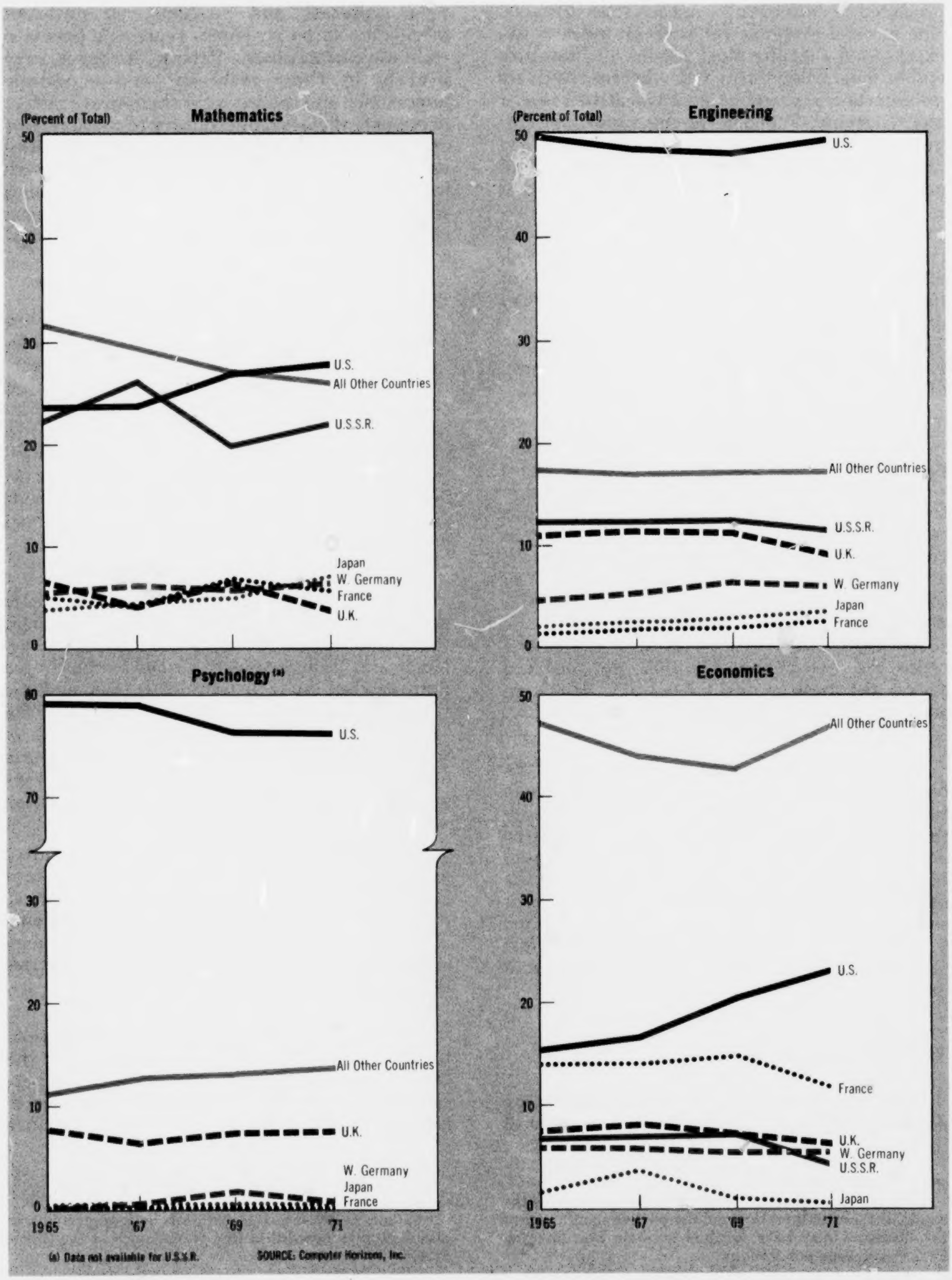
[3] For details of the methodology employed, including validation checks, see *Development of U.S. and International Indicators of the Quantity and Quality of Scientific Literature*, Computer Horizons, Inc., September 1972.

Figure 4

Scientific Literature in Selected Fields Produced by Major Developed Nations, 1965-71



SOURCE: Computer Horizons, Inc.



(a) Data not available for U.S.S.R.

SOURCE: Computer Horizons, Inc.

produced by each country in each scientific area. The general rationale for such an index is the expectation that the most significant literature will be most frequently cited, whereas relatively unimportant research articles will attract few, if any, citations. Support for the validity of this indicator is the high correlation, found in a number of studies, between the significance of papers as judged by researchers in the field and as measured by the number of citations. However, articles may fail to be noticed because of the language or journal in which they are published, whereas others may be heavily cited because of the criticisms they provoked or because they describe a minor improvement in methodology. These and similar limitations of the indicator, however, are minimized by the extremely large number of citations involved in the present case.

The data source for the "significance" indicator was the *Science Citation Index*, which includes all publications cited in the 500 journals used in this study. The total number of citations received by the literature from each country in each area was divided by the number of research articles produced by the particular country in that scientific area. The resulting "citation/publication" ratios were determined for the years 1965, 1967, 1969, and 1971. Since the ratios did not change significantly over the period, the mean annual value was used. These data are presented in figure 5.

Overall, the U.S.-produced literature had the highest "significance" ratio in five of the seven fields, with systematic biology and mathematics the two exceptions. ("Economics" was omitted because of the lack of reliable citation data.) Literature of the United Kingdom received the next highest rankings, placing either first or second in each field. Ranking after the United States and the United Kingdom were West Germany, Japan, U.S.S.R., and France, in that order.[4]

The "Patent Balance"

Data on patent applications and awards are also measures of inventive output. Inventions of new processes and products, of sufficient originality to be patented, represent potential technological advances. Patents, however, vary greatly in their technical and economic importance and the basis for their award differs in important ways from country to country. Not only does the rigor of the tests for originality vary, but there are also considerable differences in the relative success of litigation involving patent rights; this determines the relative ease and value of obtaining patents in different countries.

The absolute number of patent applications or awards in individual countries is not an adequate indicator for the purposes of international comparisons. It is more meaningful to compare the number of patents awarded to nationals with those awarded to foreigners in each country.[5] This yields an index which reflects the relative success of countries in developing products and processes of sufficient potential significance to warrant international patent protection.

Figure 6 presents the total number of patents awarded to U.S. nationals by five countries (United Kingdom, U.S.S.R., West Germany, Japan, and France), those awarded by the United States to nationals of these countries, and the resulting U.S. balance. This shows that the "patent balance" of the United States fell by some 40 percent between 1966-70. The decline is due principally to the reduced number of patents awarded to U.S. nationals by foreign countries.

Since patent applications in a foreign country are usually the result of simultaneous patent application in the applicant's own country, these data indicate that the rate of growth of patentable ideas of international merit have been expanding at a greater rate in other countries than in the United States.

The patent balance of the United States relative to each of the other countries (except the U.S.S.R. which accounts for less than one percent of the total patent transactions considered) is presented in figure 7. Overall, the U.S. balance

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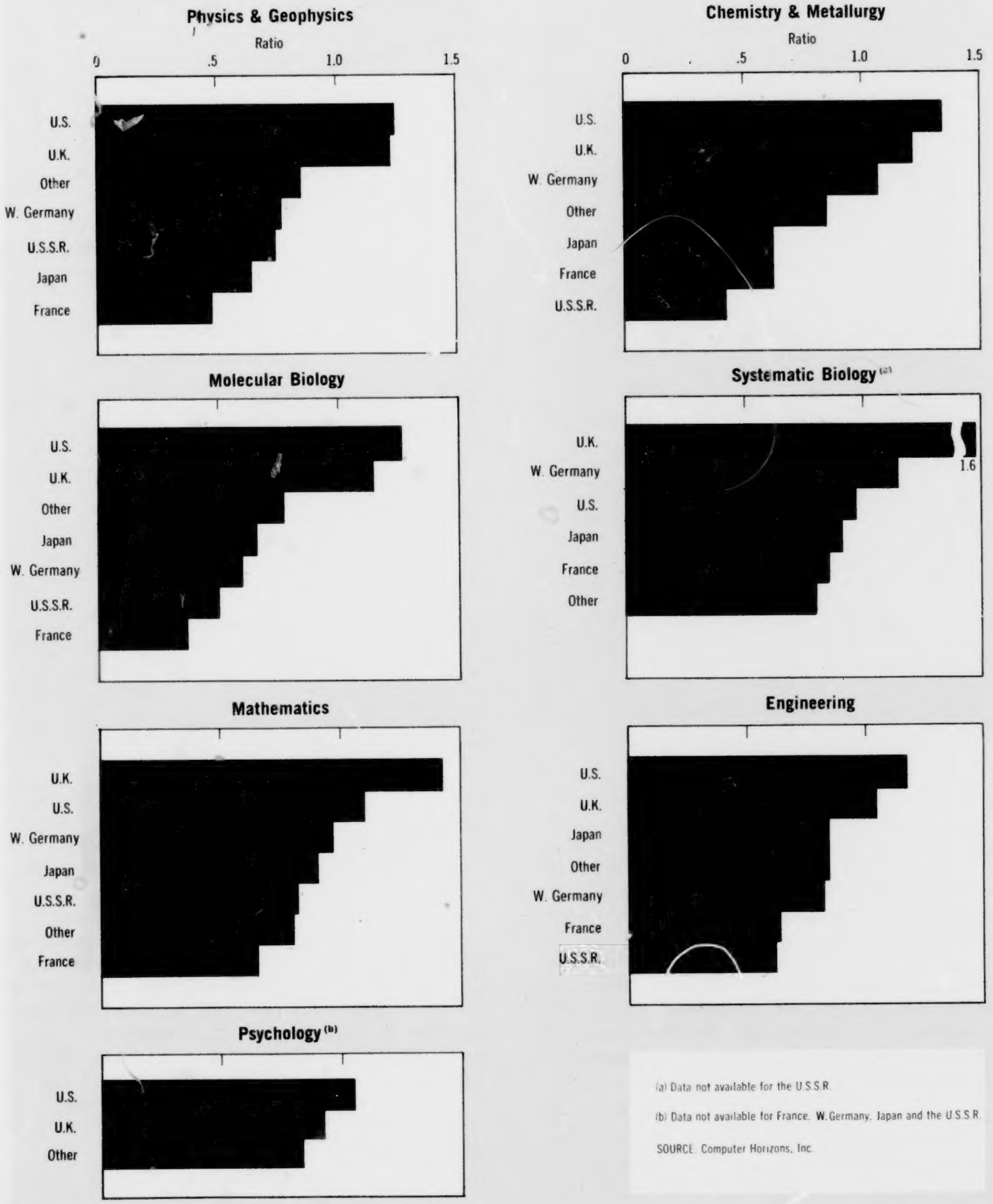
[4] The particular sample of journals used in estimating the national origins of literature and the relative significance of the literature may have resulted in some bias favoring English-language publications.

[5] Patents awarded to U.S. nationals by foreign countries minus patents awarded to foreign nationals by the United States.

Figure 5

Citation/Publication Ratio of Scientific Literature in Selected Fields [Mean Values for 1965-71]



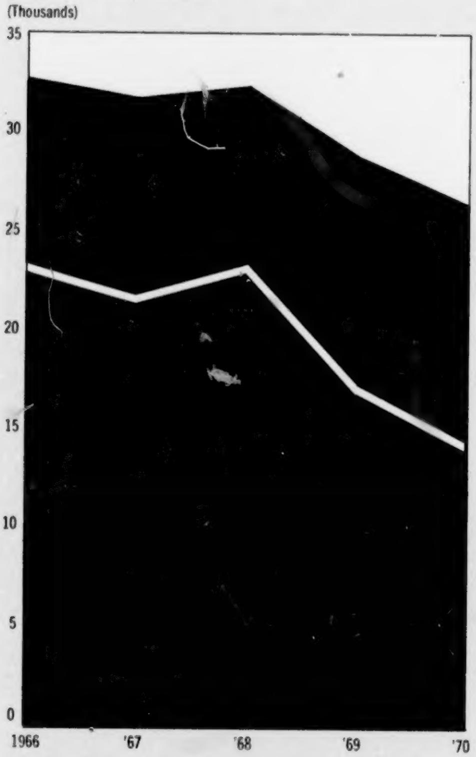
(a) Data not available for the U.S.S.R.

(b) Data not available for France, W. Germany, Japan and the U.S.S.R.

SOURCE: Computer Horizons, Inc.

Figure 6

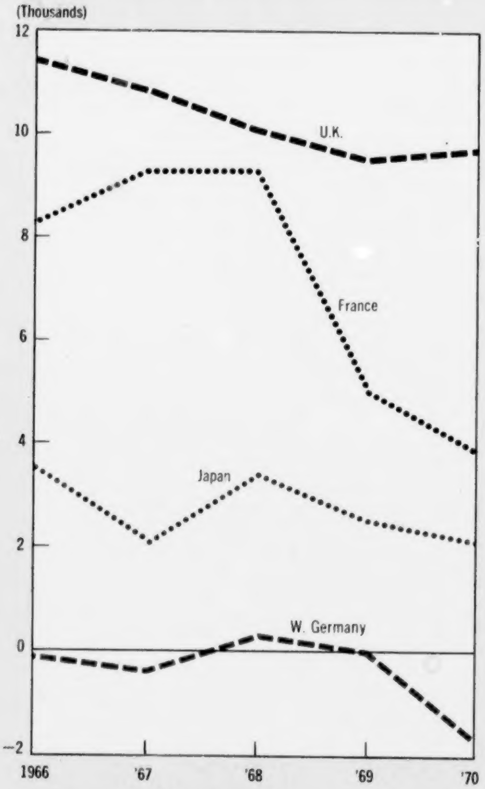
Patents Awarded to U.S. Nationals by Foreign Countries and to Foreign Nationals by the U.S. 1966-70



SOURCE: World Intellectual Property Organization, Geneva.

Figure 7

U.S. Patent Balance with Selected Countries, 1966-70



SOURCE: World Intellectual Property Organization, Geneva.

declined in each country, with the major reduction occurring in respect to France, followed by smaller declines in relation to the United Kingdom, Japan, and West Germany in that order. Declines in the U.S. balance vis-a-vis France, United Kingdom, and West Germany were due principally to reductions in the number of patents awarded to U.S. nationals; conversely, the decline with respect to Japan was produced largely by an increasing number of awards to that country by the United States.

Thus, the U.S. patent position, while still favorable in 1970, was eroding for two reasons: (a) a declining number of foreign patents of U.S. origin and (b) an increasing number of U.S. patents of foreign origin.

PRODUCTIVITY, TECHNOLOGY TRANSFER, AND BALANCE OF TRADE

Science and technology play an important role in industrial innovation, productivity, economic growth, and trade among nations. They represent, however, only one component in the complex matrix of factors which determine the technological and economic position of a nation. The numerous other variables involved (legal, financial, social, market, etc.) make it difficult to specify the exact role and contribution of any single factor—such as R&D.

In discussing productivity, technology transfer, and balance of trade, comparisons are limited to those areas and aspects which depend upon R&D in rather direct and obvious ways.

Productivity

Productivity expresses the relationship between the quantity of goods and services produced (the output) and the resources (e.g., labor, capital, land, and energy) used to produce them (the input). One of the most commonly used indices of productivity is "output per man-hour," which relates output to the input of labor time. R&D contributes to productivity by providing advances in technology which increase output per man-hour. All studies of the effects of R&D on productivity growth conclude that there is a direct relationship which is "positive, significant, and high."[6]

Indices now available do not permit comparison of absolute levels of productivity in different countries, except in the case of certain individual industries. Instead, comparisons are limited to changes in productivity which occur over time in individual countries. Normalized data for changes in relative labor productivity in manufacturing are presented in figure 8 for the United States, United Kingdom, France, West Germany, and Japan.

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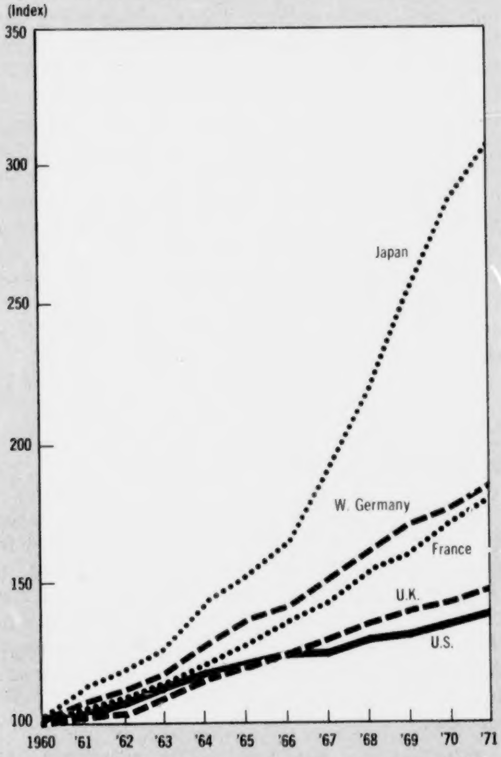
[6] *Research and Development and Economic Growth/Productivity,* Papers and Proceedings of a Colloquium, National Science Foundation, NSF 72-303, December 1971.

Figure 8

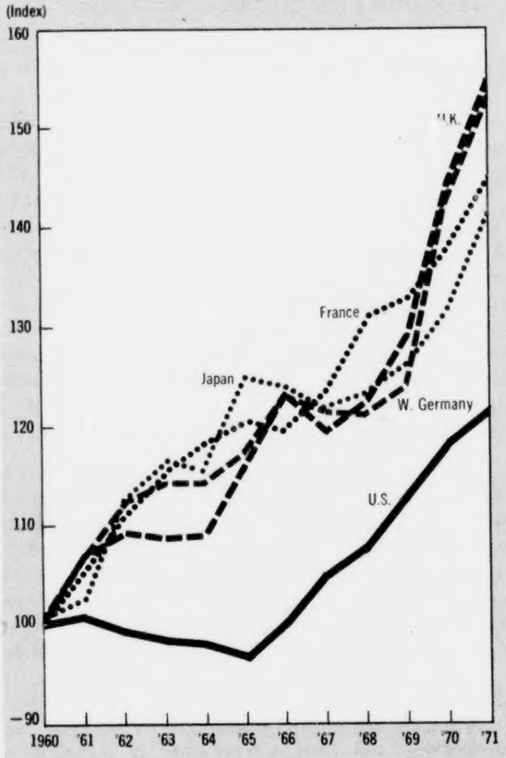
Productivity in Manufacturing Industries, by Country, 1960-71 [Index 1960 = 100]



SOURCE: U.S. Department of Labor.

Figure 9

Unit Labor Cost in Manufacturing Industries, by Country, 1960-71 [Index 1960 = 100]



SOURCE: U.S. Department of Labor.

Japan increased its productivity by 210 percent between 1960-71, compared to about a 39-percent increase in the United States. Productivity gains in manufacturing over the same period were 86 percent for West Germany, 81 percent for France, and 50 percent for the United Kingdom. Of course, the United States, which has already reached a high level of productivity, might not be expected to sustain the same high proportional gains as countries starting from a lower productivity base.

Increases in productivity can translate into lower product cost, providing the productivity gains offset increases in labor costs. Unit labor cost (hourly labor cost divided by output per man-hour) for manufactured products is shown in figure 9 for the same five countries. It can be seen that productivity gains were sufficient to offset increased labor costs in the United States during the 1960-66 period, but not thereafter. Productivity gains in the other four countries were also exceeded by increases in labor costs, particularly after the mid-sixties. Even in the case of Japan, the large increases in productivity after the middle of the decade were not sufficient to offset the growth in labor costs.[7]

Technological Balance of Payments

Nations often seek to improve their technological and productive position by purchasing technical "know-how" (e.g., patents, techniques, formulas, designs, franchises, and manufacturing rights) from other countries. Many factors—such as R&D and economic development policies, ownership and trading arrangements, and marketing effectiveness—may influence the actual level and balance of technology transfer between nations. A persisting favorable balance of payments for technical "know-how," however, is an indicator of a strong position in technology.

Data on payments and receipts for technical "know-how" are available for transactions between multinational companies and their foreign affiliates as well as between independent organizations. The latter data were selected for use here primarily because of the greater element of valuation implicit in transactions between independent enterprises. It should be noted, however, that the omission of transactions between corporations and their foreign affiliates results in a substantial understatement of the extent of technology transfer. In addition to transactions involving financial exchanges, a considerable amount of technical "know-how" is transferred informally between multinational firms and their foreign affiliates.

The technological balance of payments with respect to the United States is presented in figure 10. Included are U.S. receipts from the sale of technical "know-how" to all countries, payments by the United States to all other countries for such "know-how," and the resulting balance of payments (receipts minus payments). The United States had a strong and increasingly positive balance of payments in this area throughout the decade. U.S. receipts from the sale of "know-how" grew exponentially while its payments—which were some four to five times less than receipts—rose linearly.

The U.S. balance of payments associated with a country or countries is presented in figure 11. This shows that the principal increase in the U.S. balance is attributable to Japan which more than tripled its purchase of technical "know-how" from the United States between 1966-71. Purchases by the United States from Japan, on the other hand, remained at a very low level (only 2 to 4 percent as much as Japan's purchases from the United States) throughout the period. Western Europe (mainly the Common Market countries) also contributed to the favorable U.S. balance; however, purchases by the United States from Western Europe, which were much greater than those from Japan, were some 40 percent as large as U.S. receipts from these countries for technical "know-how."

Balance of Trade in Technology-Intensive Products

A nation's balance of trade depends upon many factors including the relative price of its products, the effectiveness of its marketing, its trading arrangements with other countries, and its relative position in industrial technology. The technology position, in turn, is increasingly dependent upon the use of R&D to improve and develop new industrial products, processes, and services.

This relationship between industrial technology and R&D provides a basis for dividing

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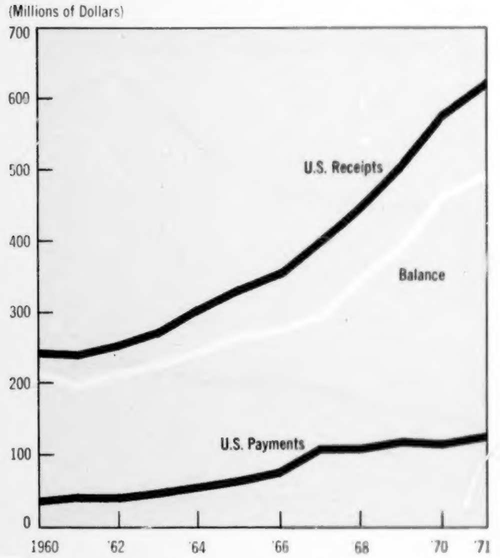
[7] A detailed and comprehensive study of unit labor cost, productivity, and labor compensation is presented in *Competitiveness of U.S. Industries*, United States Tariff Commission, TC Publication 473, Washington, D.C., April 1972.

Figure 10

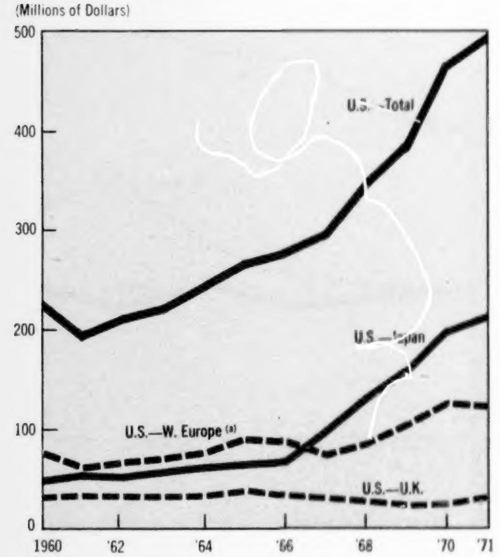
U.S. Payments and Receipts for Patents, Manufacturing Rights, Licenses, Etc., 1960-71



SOURCE: U.S. Department of Commerce.

Figure 11

U.S. Balance of Payments for Patents Manufacturing Rights, Licenses, Etc., by Country, 1960-71



(a) Except U.K. SOURCE: U.S. Department of Commerce.

manufactured products into two groups: technology-intensive and nontechnology-intensive products. The grouping is based upon the relative extent of R&D performed by the industries which manufacture the products. Products from industries with (a) 25 or more scientists and engineers engaged in R&D per 1,000 employees and (b) 4 percent or more of their net sales directed to R&D are designated here as "technology-intensive" products while those with a lower level of R&D investment are regarded as "nontechnology-intensive" products. Based on these criteria, the product areas which are technology-intensive are (a) chemicals, (b) nonelectrical machinery, (c) electrical machinery, (d) aircraft and parts, and (e) scientific and professional instruments. All other manufactured products are regarded as nontechnology intensive.[8]

The U.S. trade balance (exports minus imports) associated with these two categories of products is shown in figure 12. The favorable balance in technology-intensive industries is clearly indicated; the balance doubled over the 1960-71 period. In contrast, the United States had a large and increasing deficit trade balance in nontechnology-intensive products.[9]

The favorable U.S. export position in high technology products results in large measure from the extensive use of scientists and engineers as well as other skilled manpower.[10] Thus, the U.S. comparative advantage for international trade in manufactured products appears to be in the export of goods that are intensive in the use of highly educated and skilled personnel rather than in low technology mass-produced goods.

The favorable U.S. trade balance in the tech-

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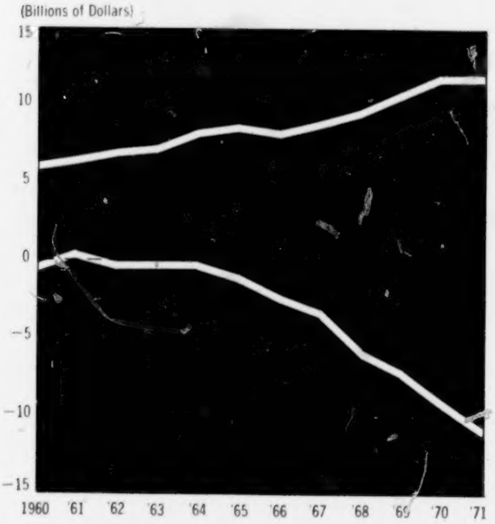
[8] This grouping, of course, is an approximate one. Products and industries, although highly correlated at the gross level, do not perfectly coincide, with the result that not all products manufactured by a high R&D-performing industry are technology-intensive. Further, the criteria used here result in placing "automobile and parts" products in the nontechnology-intensive group, instead of the other group where they are sometimes assigned.

[9] The U.S. trade position may also be viewed in terms of capital and consumer goods. The favorable U.S. export performance is largely accounted for by capital goods, almost all of which are produced by technology-intensive industries, while the unfavorable import situation lies largely in consumer goods.

[10] W. H. Bronson and H. B. Junz, "Trends in U.S. Trade and Comparative Advantage," *Brookings Papers on Economic Activity*, 2, 1971.

Figure 12

U.S. Trade Balance in Technology- and Nontechnology-Intensive Manufactured Products, 1960-71



SOURCE: U.S. Department of Commerce.

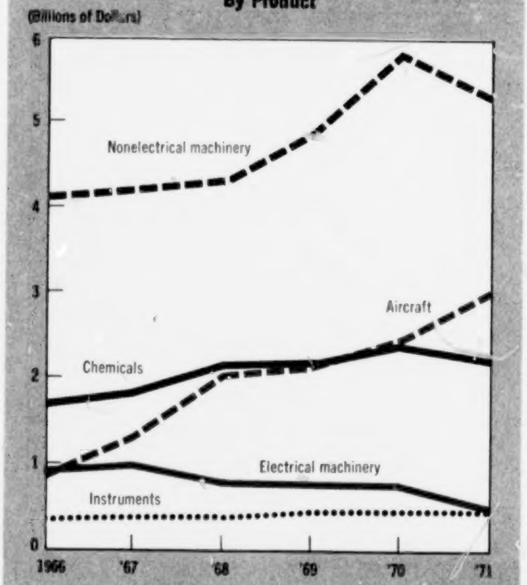
nology-intensive area is shown in figure 13 for each of the five industry groups.

- Nonelectrical machinery declined in net exports during 1971. The decline was primarily due to the continuing rise in imports of office and textile machinery. Computers and construction and mining equipment account principally for the net export position.
- Aircraft and parts had a 9:1 export/import ratio in 1971. Although this has been the fastest growing exporting industry, there are signs that the favorable ratio may decline in the near future.
- Chemical net exports declined in 1971 chiefly due to increased imports of chemical elements and compounds as well as medicinal and pharmaceutical products; major net export products were plastics and resins and radioactive materials.
- Instruments maintained a steady but small growth in net exports.

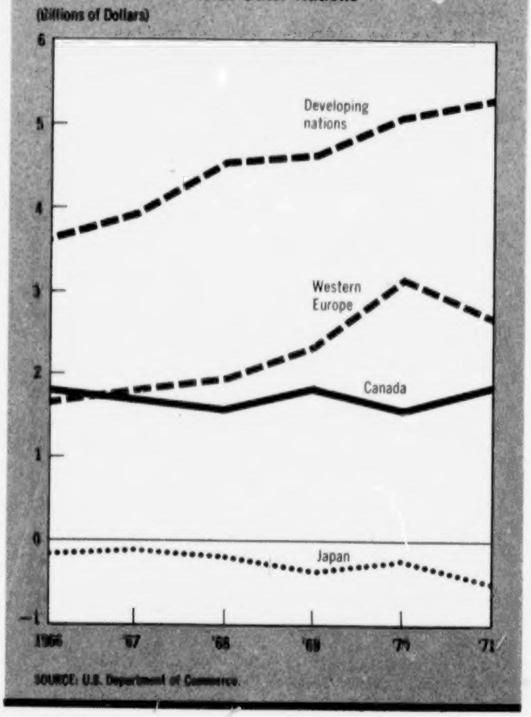
Figure 13

U.S. Trade Balance in Technology-Intensive Products, 1966-71

By Product



With Other Nations



SOURCE: U.S. Department of Commerce.

- Electrical machinery continued its rapid decline in net exports, principally as a result of imports of telecommunication apparatus.

This mixture of growing and declining exports illustrates the complexities of the present U.S. trade position. The underlying dynamics of the position, however, are partially explained by the "product cycle" concept.[11] Trade in manufactured goods, according to this concept, typically follows a cycle in which the United States initially establishes a net export position with the introduction of a new product, maintains this position until the technologies and skills necessary for manufacturing the product are developed elsewhere, and then becomes an importer as the production is standardized and moves abroad to minimize costs. The concept implies that the product structure of U.S. exports must have a continuous infusion of new products in order for the United States to maintain a favorable trade position.

The favorable position of the United States in high technology areas is based primarily on exports to developing nations and countries of Western Europe (figure 13). In 1971, developing nations accounted for 55 percent of the net exports in these areas, and Western Europe almost 30 percent. In contrast, the deficit balance in the high technology area developed with Japan in the mid-1960's and persisted in the following years, with the largest increase (almost 120 percent) occurring in 1971. This deficit lies primarily in electrical machinery (particularly in consumer electronics), and to a lesser extent in the instrument and nonelectric machinery areas. Only in the aircraft and parts area does the United States have a significant net export position with respect to Japan.

Although the United States still retains a strong position as a net exporter of technology-intensive products, various indicators suggest that the position may deteriorate in the near future. Not only did the overall trade balance for high technology industries level off between 1970-71, but the two industries most responsible for the favorable balance in previous years (nonelectrical machinery and chemicals) had their first decline in net exports in 1971. Furthermore, net exports of electrical machinery appear to be declining at a faster rate than in recent years; the shift of exports in this area from developed to developing nations is regarded as a further indication that these products are moving from the export to the import stage. In addition to these relatively direct indicators of the U.S. trade position, other indices suggest that R&D trends in these industries may contribute to a deteriorating position in the future: the "R&D intensiveness" of the five industries as a whole declined by some 25 percent in recent years and expenditures for R&D fell by almost 10 percent between 1968-70, as noted elsewhere in this report.

The preceding examination of foreign trade was restricted, for the purposes of this report, to those aspects which provide relatively direct indices of the position and performance of U.S. technology. As a result, the whole area of foreign direct investment and sales of U.S. subsidiaries abroad was neglected.[12] Such sales, mostly in technology-intensive products, exceed exports by some 2.5 times, but are highly correlated with the export position of the individual industries. The large and growing investment income from foreign subsidiaries of the United States helps to finance U.S. imports of nontechnology-intensive products. Furthermore, such investment in developing nations probably generates a considerable market for the export of U.S. technology-intensive products.

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[11] R. Vernon, "International Investment and International Trade in the Product Cycle," *Quarterly Journal of Economics*, v. 80, May 1966.

[12] A comprehensive discussion of these and related topics is presented in: P. G. Peterson, *The United States in the Changing World Economy*, U.S. Government Printing Office, 1971.

Resources for Research and Development

Resources for Research and Development

Indicators in this chapter deal with the financial and human resources employed in research and development. These include measures of the total national R&D effort, in terms of the level and sources of funding; the character of R&D (basic research, applied research, and development); and the scientists and engineers engaged in these activities. The general areas of R&D and the institutions involved are indicated, although these aspects are more fully treated in subsequent sections of the report.

In this chapter resources are viewed both as inputs to the scientific-technological enterprise and as indicators of the level of its R&D. The use of financial resources as a surrogate for level of R&D activity requires that the purchase value of the dollar be adjusted to reflect rising costs. In the absence of an "R&D price index," the implicit price deflator for the gross national product is used to convert R&D expenditures from current to constant dollars; this conversion, it is recognized, may not fully account for the increasing costs associated with R&D.

INDICATOR HIGHLIGHTS

- National expenditures for R&D increased throughout the 1961-72 period when expressed in current dollars; in terms of constant 1958 dollars, however, expenditures declined 6 percent between 1968 and 1971, but increased slightly in 1972 to a level equivalent to that of 1966-67.

- Total R&D expenditures as a proportion of the gross national product declined to 2.5 percent in 1972 from a high of 3.0 in 1964; the decline was due to continued growth of the GNP coupled with the reduced growth of Federal R&D expenditures.

- Federal Government expenditures for R&D in current dollars leveled off after 1968 and declined slightly thereafter—primarily as the result of reduced expenditures for space R&D—before rising in 1971 and 1972; the result in constant 1958 dollars was a reduction which continued through 1971 and amounted to a 12-percent decline.

- The number of scientists and engineers engaged in R&D reached almost 560,000 in 1969 before declining each year thereafter for a total reduction of some 35,000 by 1972; almost all the decline occurred in the industrial sector.

- Most affected by the funding reductions were development activities which leveled off in 1970 before rising again in 1971 and 1972; in constant 1958 dollars, however, expenditures for development declined after 1969 and remained at the lower level through 1972.

- The fraction of total Federal outlays devoted to R&D fell from 12 to 7 percent between 1965-72. The decline was due in large part to the growth of Federal expenditures in areas which have small R&D outlays, such as income security, and to reductions in space R&D.

- Some 73 percent of all Federal R&D expenditures in 1972 went for national defense and space exploration. National defense received 54 percent of total Federal R&D funds in 1972 and space exploration received some 19 percent of the total.

- Federal expenditures for R&D in civilian areas (areas other than national defense and space) increased throughout the 1963-72 period, rising to 27 percent of the total in 1972, up from 14 percent in 1963. Areas receiving the bulk of funds in 1972 were health (8.7 percent), advancement of science and technology (4.4 percent), transportation (3.8 percent), environment (3.2 percent), and energy conversion and development (2.5 percent).

- Total expenditures for industrial R&D in current dollars increased until 1969, declined in 1970, and then rose in 1971 and 1972; the trend in constant 1958 dollars, however, was one of considerable declines after 1969 and a small increase in 1972, leaving expenditures at their 1965-66 level.

- Industry-funded R&D, which rose in current dollar expenditures throughout the 1961-72 period, is devoted to applied research and development in the electrical equipment, aircraft and missiles, motor vehicles, chemical, and machinery industries. Some 80 percent of Federal expenditures for industrial R&D went to the first two industries in 1970.

- Federal funds for industrial R&D leveled off in the mid-1960's and declined in current dollars after 1969—primarily because of reduced expenditures for space R&D—while industry continued to increase its expenditures, with the result that in 1968 industry replaced the Federal Government as the prime source of support for industrial R&D.

- Universities and colleges, which provided 4 percent of the Nation's R&D funds in 1972, concentrate their expenditures on basic and applied research in the life sciences (almost 50 percent), physical sciences and engineering (20 percent), and the social sciences (16 percent).

■ The Nation devotes a sizable share of its human, institutional, and financial resources to research and development. The largest proportion of these resources is directed toward the achievement of national objectives in areas such as defense, health, space, energy, and the environment. A somewhat smaller share of the resources goes for developing the technological basis for new and improved industrial products and services. And a considerably smaller share is used for improving the fundamental understanding of man and nature.

NATIONAL RESOURCES FOR RESEARCH AND DEVELOPMENT

Total U.S. expenditures for R&D are shown in figure 14 for 1961-72 in both current and constant (1958) dollars. Current dollar expenditures rose throughout the period. As measured in constant dollars, however, expenditures peaked in 1968, and declined by 6 percent over the next 3 years to a level equivalent to 1966. Slightly increased expenditures are estimated for 1972. (Coincident with the constant dollar declines were nearly equivalent proportional reductions in the total number of scientists and engineers engaged in R&D, as shown in figure 15.)

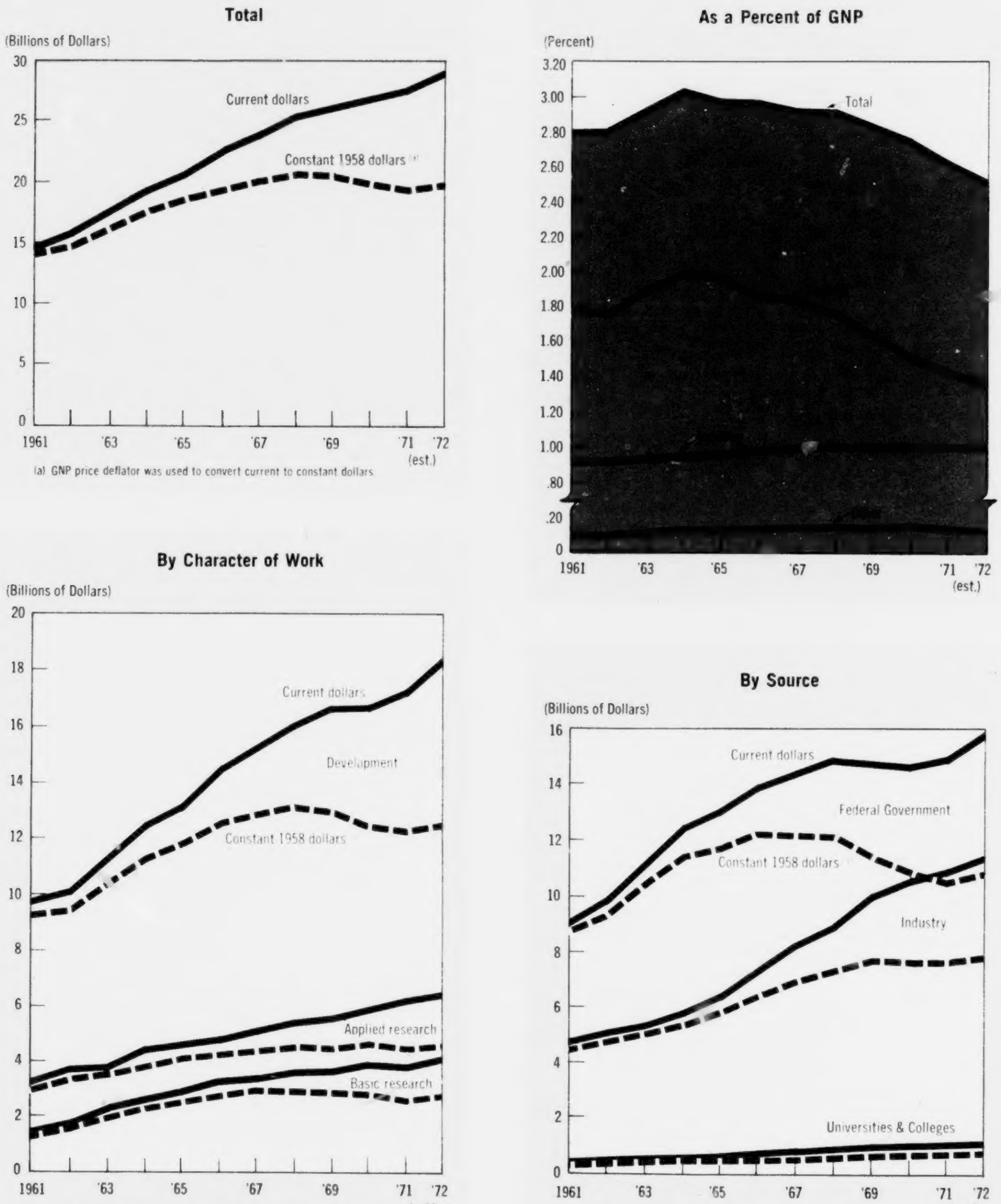
As a part of its gross national product, the United States is estimated to have devoted 2.5 percent of GNP to R&D in 1972. This ratio, which reached its highest level of 3.0 percent in 1964, has declined steadily since 1967 (figure 14). The reduction is attributable to the continued growth of the GNP coupled with declines in R&D expenditures by the Federal Government; non-Federal expenditures for R&D remained at approximately 1.2 percent of GNP between 1967-72.

The principal sources of R&D funds are the Federal Government which provided 55 percent of the nation's total R&D expenditures in 1972, private industry 40 percent, and the universities and colleges 4 percent. Other nonprofit institutions contributed the remaining 1 percent (figure 14). Government funding in current dollars declined slightly between 1968 and 1970 and increased in 1971 and 1972; in constant dollars, however, Federal funding declined by 12 percent between 1968-71 before increasing slightly in 1972. Federal expenditures for R&D in FY 1973 are estimated at approximately $16.5 billion, a 3-percent increase over expenditures for FY 1972, which were in turn 6 percent higher than FY 1971.

Expenditures for R&D in terms of the character of work—basic research, applied research,

Figure 14

National R&D Expenditures, 1961-72



(a) GNP price deflator was used to convert current to constant dollars.

(a) GNP price deflator was used to convert current to constant dollars.

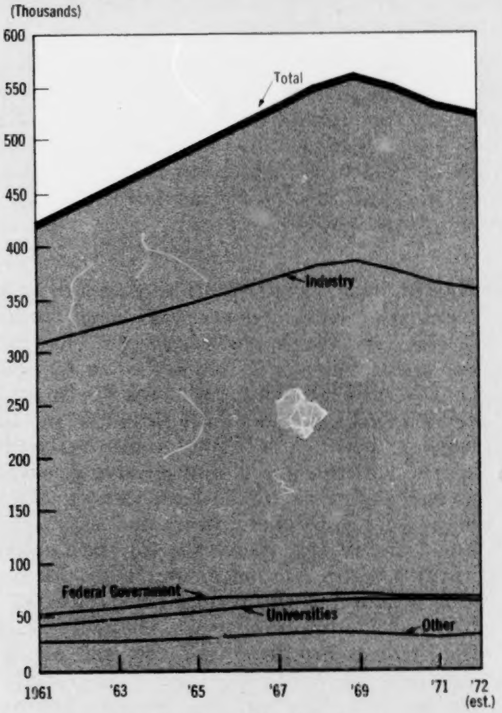
SOURCE: National Science Foundation.

(a) GNP price deflator was used to convert current to constant dollars.

NOTE: Other nonprofit institutions R&D expenditures increased from $110 million in 1961 to $235 million in 1972.

Figure 15

Scientists and Engineers[a] Employed in R&D, by Sector, 1961-72



(a) Includes all scientists and engineers (full-time-equivalent basis).

SOURCE: National Science Foundation.

and development—are shown in figure 14. The most salient change appears in the development area in which constant-dollar expenditures declined during 1969-71. This decline accounts in large part for the overall R&D reduction noted in figure 14. In 1972, development activities accounted for 64 percent of total R&D expenditures, applied research 22 percent, and basic research 14 percent.

A part of the nation's human resources devoted to R&D are the scientists and engineers who are engaged in performing research and development. Their total number reached almost 560,000 in 1969 before declining in each subsequent year for a total reduction of some 35,000 by 1972. Almost all the decline occurred in the industrial sector (figure 15). Industry had two-thirds of the nation's total scientists and engineers engaged in R&D (on a full-time-equivalent basis) in 1972 as compared with the universities and the Federal Government, each of which had some 13 percent.

FEDERALLY FUNDED R&D AND NATIONAL OBJECTIVES

R&D resources and activities can be related to the national functions they serve, such as defense, space, natural resources, commerce and transportation, and health. Federal expenditures for R&D[1] in these functional areas reflect the extent to which R&D is used by the government in the pursuit of national goals.

Total Federal Outlays and R&D Expenditures

Federal expenditures for R&D, expressed as a percentage of total Federal outlays, declined appreciably after 1965, as shown in figure 16. The reduction resulted from a mixture of (a) rapid growth of Federal outlays in areas which have small R&D expenditures, (b) diminished expenditures for space R&D, and (c) relative decline in expenditures for national defense, as a proportion of total Federal outlays. Federal expenditures for retirement, disability, and unemployed, for example, rose from 20 to 29 percent of total Federal outlays between 1968 and 1972; R&D expenditures, however, were less than 1 percent of the total outlays in this area. In the space area, R&D expenditures declined both in absolute terms and as a percent of total Federal outlays. Total outlays for defense, which has been the major source of R&D funds, fell from 49 percent of all Federal outlays in 1963 to 35 percent in 1972. (For further detail, see *An Analysis of Federal R&D Funding by Function*, National Science Foundation, NSF 72-300.)

R&D Activities in Functional Areas

Expenditures for the 10 major areas of federally funded R&D are presented for the years 1963-72 in figure 17.[2] These areas

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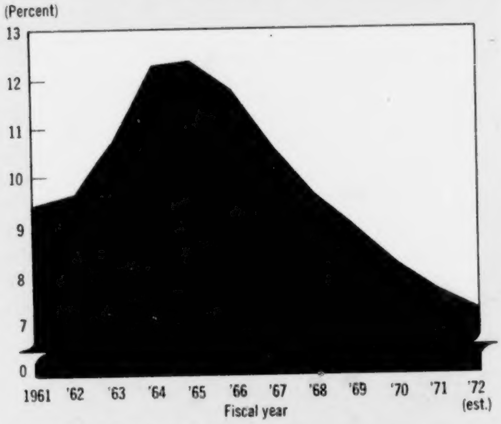
[1] Expenditure data for other funding sources (e.g., industry) are not available for these functional areas.

[2] Comparable data are not available for earlier years.

Figure 16
Federal R&D Expenditures as a Percent of Total Federal Outlays, FY 1961-72



SOURCE: National Science Foundation.

accounted for 99 percent of all Federal expenditures for R&D in 1972. The most salient features represented in the figure are:

- The large role of defense R&D throughout the period
- The rise and fall of space R&D
- The relatively rapid growth in civilian areas.

Defense R&D expenditures between 1963-72 ranged from 48 to 64 percent of total Federal expenditures for R&D. In 1972 they accounted for 54 percent, the highest proportion since 1964. Current dollar expenditures for 1972 were the highest of the 1963-72 period. The 1972 R&D expenditures in this area were directed in the main to development of missiles, aircraft, equipment, and to defense-related atomic energy activities, military sciences, and astronautics.

R&D expenditures for space in 1972 were at their 1963-64 level after declining by more than 40 percent (in current dollars) since the peak year of 1966.[3] The area, however, still received 19 percent of all Federal R&D funding in 1972. The principal programs, in terms of magnitude of expenditures in 1972, were manned space flight, space science and applications, supporting activities, and space technology. Recent declines in the space area occurred largely in the manned space program.

Expenditures for R&D in civilian areas—areas other than defense and space—grew substantially throughout the 1963-72 period, rising from 14 percent of total Federal R&D expenditures in 1963 to 27 percent in 1972. The functional areas accounting for most of the civilian-oriented R&D in 1972 were:

(1) **Health,** which consists of the *development of health resources,* the *prevention and control of health problems,* and the *delivery of health care.* The first category, which accounts for some 90 percent of all Federal expenditures for health-related R&D, includes activities of (a) the 10 National Institutes of Health which deal with specific chronic and communicable diseases as well as general medical sciences, development of health manpower, and establishment of biologic standards; (b) the mental health, health statistics, and overseas research activities of the Health Services and Mental Health Administration (HSMHA); (c) the medical and prosthetic research of the Veterans Administration; and (d) the health-related activities of the Atomic Energy Commission. The second category consists of the R&D activities of the Food and Drug Administration, Bureau of Mines, and the preventive health services of HSMHA. The delivery of health care category is comprised of the HSMHA programs in health services planning and development, health services delivery, and Indian health services. Expenditures for R&D in the entire health area, as a fraction of total Federal R&D expenditures, rose from 5.2 percent in 1963 to 8.7 percent in 1972.

(2) **Advancement of Science and Technology,** which is aimed at strengthening the Nation's scientific base and at application of science and technology to problems of national concern. The largest category is *general science,* comprised principally of basic research projects in the various scientific disciplines supported by the National Science Foundation and most of the physical science research programs (except for controlled thermonuclear research) of the Atomic Energy Commission. A second category is

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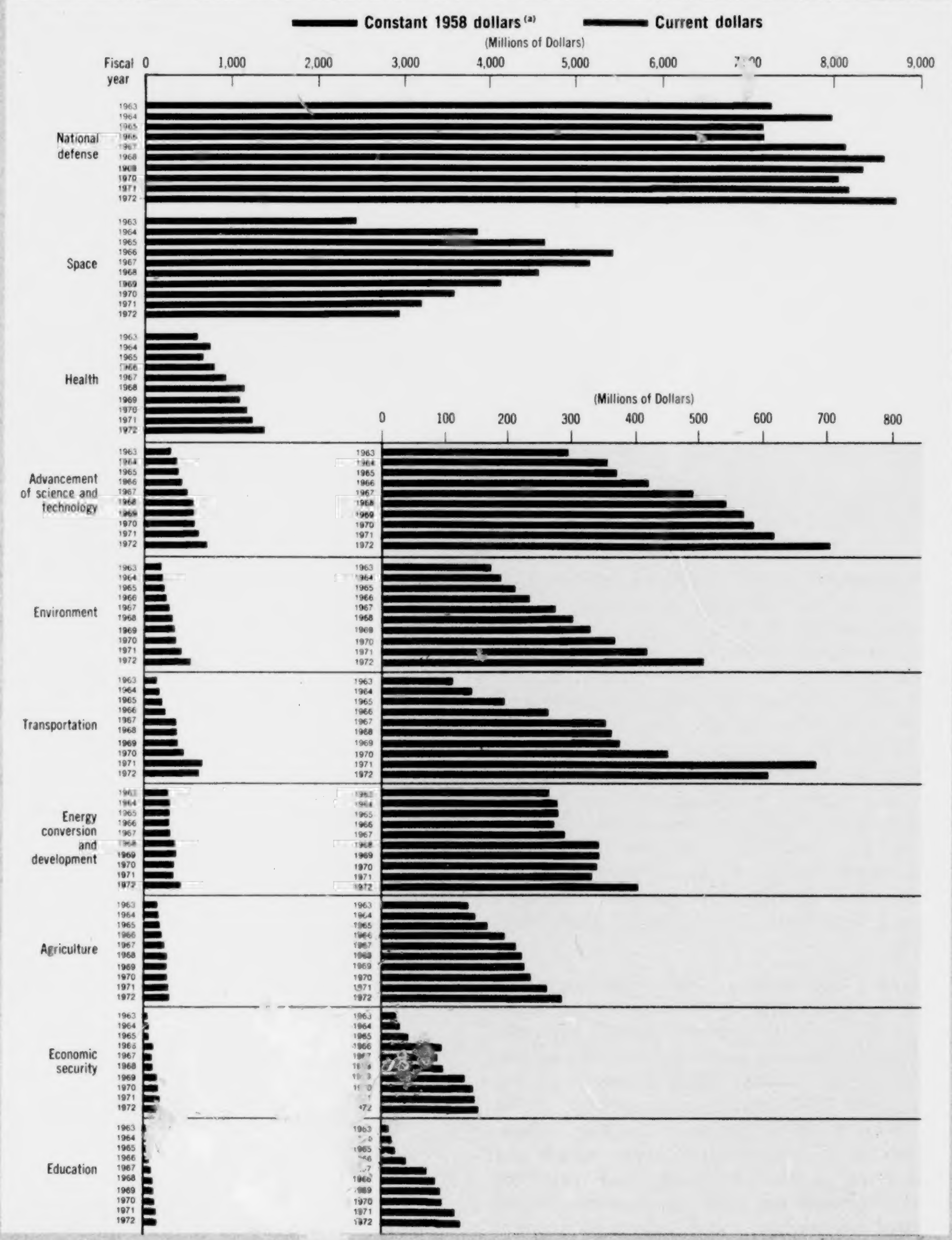
[3] The entire activities of NASA are reported as R&D or related support; the R&D component was reported as 98 percent of the agency's total expenditures in 1972.

Figure 17

Federal R&D Expenditures for Selected Functions, FY 1963-72



(a) GNP price deflator was used to convert current to consta [illegible]

SOURCE: National Science Foundation.

the *technology improvement and innovation* programs of the National Bureau of Standards. As a fraction of total R&D expenditures by the Federal Government, this area rose from 2.6 percent in 1963 to 4.4 percent in 1972.

(3) **Transportation,** which consists of R&D in air, ground, and water transportation. *Air transportation* R&D (which accounted for 70 percent of Federal expenditures for all transportation R&D in 1972) includes NASA's aeronautical technology program, and the activities of this agency and the Department of Transportation in the areas of system safety and future generations of aeronautical vehicles. *Ground transportation* R&D is aimed largely at improved highway and automotive safety and at rapid transit systems. R&D in *water and multimodal transportation* includes programs of the U.S. Coast Guard, Maritime Administration, and others. Expenditures for transportation R&D, as a fraction of all Federal R&D expenditures, increased from 1.0 percent in 1963 to 3.8 percent in 1972.

(4) **Environment,** which encompasses the *pollution control and abatement* programs of the Environmental Protection Agency and the environmental research programs of the Atomic Energy Commission; *resource development and management* which includes programs of the Forest Service, National Oceanic and Atmospheric Administration (NOAA); Office of Saline Water, and others; and *resource monitoring, measuring, and forecasting* consisting of the R&D activities of the Geological Survey and NOAA. As a fraction of total R&D expenditures by the Federal Government, R&D spending in this area increased from 1.5 percent in 1963 to 3.2 percent in 1972.

(5) **Energy Conversion and Development,** which consists mainly of *development of nuclear energy capabilities* (85 percent of R&D expenditures) and the *development and utilization of nonnuclear energy resources.* Nuclear energy activities are concentrated on development of the liquid-metal fast breeder reactor; major efforts in the nonnuclear area—which are rising in both absolute and relative terms—center on coal gasification, oxide control technology, and advanced underground electric transmission lines. R&D expenditures in this area, as a proportion of all Federal R&D outlays, rose from 2.3 percent in 1963 to 2.5 percent in 1972.

(6) **Agriculture,** includes R&D activities aimed at *increasing the quantity and improving the quality of agricultural products* and *expanding the utilization of agriculture resources.* The first category, which comprised more than 90 percent of total R&D expenditures throughout 1963-72, includes the efforts of the Agricultural Research Services and the Cooperative State Research Service of the Department of Agriculture; R&D in the second category includes activities of the Economic Research Service and the Farmer Cooperative Service. As a proportion of all Federal R&D expenditures, those in this area were 1.2 percent in 1963 and 1.8 percent in 1972.

(7) **Economic Security,** which consists of *manpower resources development, reduction of poverty,* and *income maintenance.* R&D in this area is aimed primarily at improving the employability of individuals, promoting equality of opportunity, providing systems of income maintenance, and alleviating poverty. Expenditures for such R&D—provided primarily by the Department of Health, Education, and Welfare and the Office of Economic Opportunity—increased from 0.2 percent of total Federal R&D expenditures in 1963 to 1.0 percent in 1972.

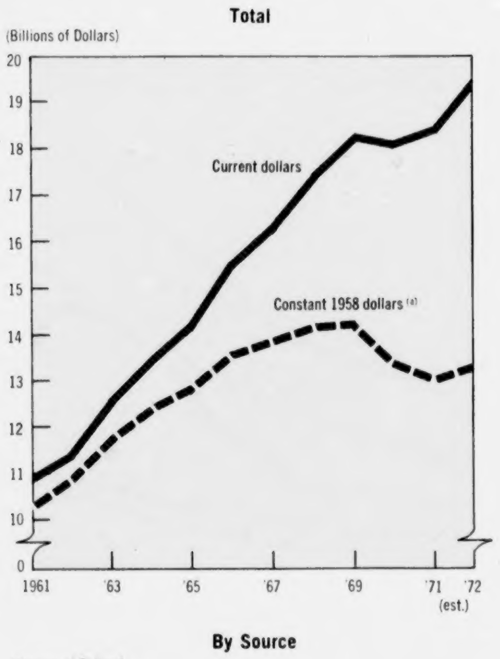
(8) **Education,** which consists of the R&D activities of the Office of Education, the National Institute of Education, and the Office of Child Development, all of the Department of Health, Education, and Welfare. R&D is spread among a wide range of efforts, including the development of improved curriculums and individualized instructional materials, better understanding of the learning process, and the motivation of disadvantaged children. The fraction of total Federal R&D expenditures for this area rose from 0.1 percent in 1963 to 0.8 percent in 1972.

RESOURCES FOR INDUSTRIAL R&D

Total expenditures for industrial R&D, which include expenditures of both government and private industry, are shown in figure 18. The separation of these two funding sources indi-

Figure 18

Industrial R&D Expenditures, 1961-72



(a) GNP price deflator was used to convert current to constant dollars.

SOURCE: National Science Foundation.

cates that the decline in total R&D expenditures in 1970 was due entirely to reductions in the level of Federal support. Federal funding actually leveled off in 1966 while industrial support rose more rapidly than in previous years, with the result that industry replaced the Federal Government in 1968 as the principal source of support for industrial research. By 1972, industry funded 58 percent of all industrial R&D compared with 43 percent in 1961.

Although Federal funding for industrial R&D did not start its decline until after 1968, the effects of a relatively slow rate of growth in funding, compared with the increasing cost of R&D, were apparent as early as 1964 in terms of the source of support for R&D scientists and engineers (figure 19).[4] The figure shows that the number of scientists and engineers supported by Federal funds started to decline after 1964, although the largest reductions did not occur until after 1969, which coincides with the onset of larger constant dollar funding reductions that are shown in figure 18.

These funding changes did not affect appreciably the relative distribution of funds among basic research, applied research, and development activities. In 1972 as in 1961, industrial R&D was concentrated in development (78 percent), while applied research received some 19 percent and basic research declined from 4 to 3 percent. (The absolute level of basic research, however, declined considerably as shown elsewhere in this report.)

Despite these funding changes, industrial firms still perform the bulk of the Nation's R&D. In 1972, funding of industrial R&D accounted for 68 percent of all R&D conducted in the United States, including 83 percent of the development, 55 percent of the applied research, and 16 percent of the basic research.

Industry-Funded R&D

R&D in this category is performed largely in the seven industries indicated in figure 20. They accounted for about 85 percent of all company R&D expenditures during the period reported. Each of these industries, except for "aircraft and missiles" and "motor vehicles," had increasing R&D expenditures (in current dollars) through

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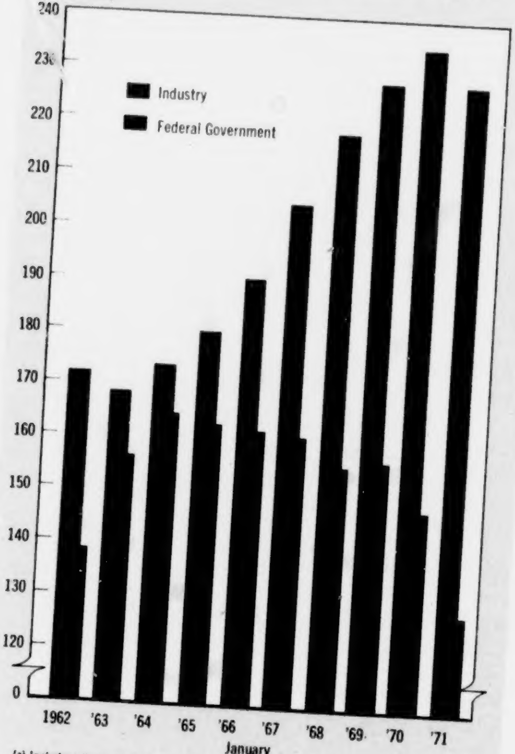
[4] Comparable data are not available for years prior to 1962.

Figure 19

Scientists and Engineers[(a)] Engaged in Industrial R&D, by Source of Funds, 1962-71



(a) Includes all scientists and engineers (full-time-equivalent basis).

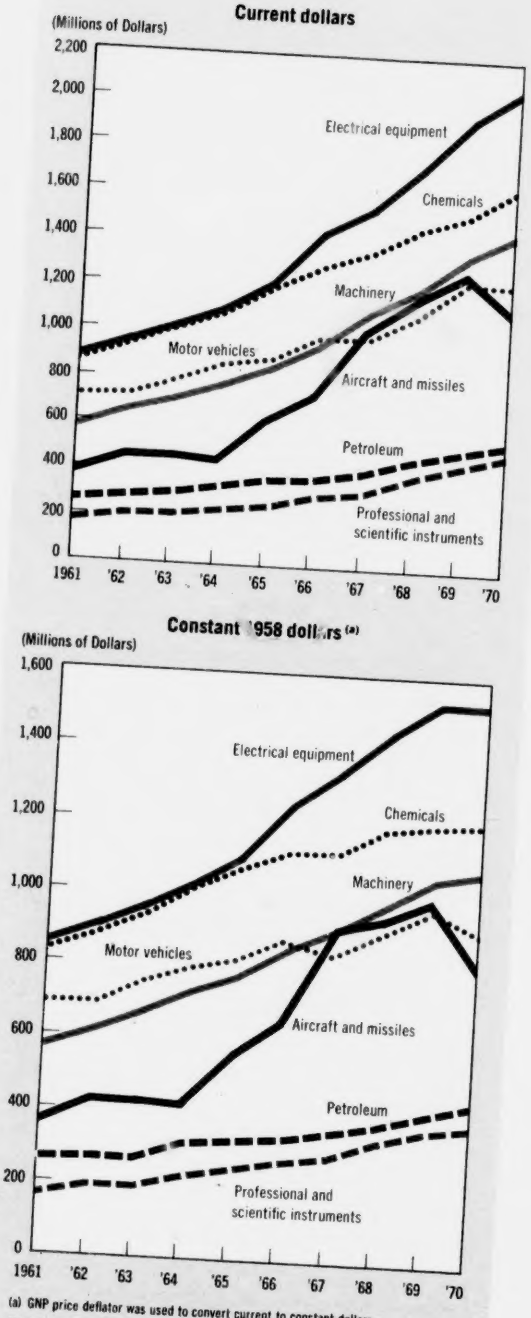
SOURCE: National Science Foundation.

1970 (the latest year for which such data are available). In terms of constant dollars, however, only the petroleum, machinery, and professional and scientific instruments industries indicated increases in 1970.

Industry-funded R&D in 1972 was concentrated in development activities which received 73 percent of the total funds as compared with 22 percent for applied research and 4 percent for basic research. This composition changed continuously over the decade toward more development (from 68 to 73 percent), less applied research (from 25 to 22 percent), and less basic research (from 7 to 4 percent). These long-term shifts do not appear to have been accelerated by recent funding changes.

Figure 20

Industry's Own Funds for R&D, by Selected Industry, 1961-70



(a) GNP price deflator was used to convert current to constant dollars.

SOURCE: National Science Foundation.

Company-funded R&D is projected to increase by about 25 percent between 1972 and 1975, rising to some $14 billion, and the number of scientists and engineers employed in such R&D is anticipated to increase to 260,000 in 1975.[5] Individual industries show some variations from these projected trends. The drug industry (a part of the larger chemical industry) anticipates increases in R&D spending which are larger than the all-industry average; electronic firms expect increases in line with the rest of industry; companies in industrial chemicals and aerospace foresee future R&D growth at a pace somewhat below the rest of industry; and petroleum firms expect only a slight increase in total R&D spending over the next few years.

Federally Funded R&D

The Federal Government funds R&D principally for defense and space purposes. In 1970, for example, all but 14 percent of the Federal funds for industrial R&D came from the Department of Defense and NASA. The funds from Federal agencies are directed to a small number of industries, with more than 90 percent of the funds going to five industries: aircraft and missiles; electrical equipment and communication; machinery; motor vehicles and other transportation equipment; and professional and scientific instruments. Some 80 percent of all Federal expenditures for R&D in industry go to the first two industries.[6]

Federal funds are concentrated in development activities, more so than are the funds supplied by industry. On the average throughout the 1961-72 period, development received about 85 percent of the total funds, applied research 12-14 percent, and basic research 2 percent. The funding reductions noted above had the greatest absolute effects on development activities, expenditures for which peaked in 1966 and subsequently declined 25 percent in constant dollars between then and 1972. (Estimated current dollar expenditures indicate a small increase in 1972.) Similarly, the 1972 funding level for applied research declined by 18 percent after its peak funding year of 1962. But proportionally, basic research was even more adversely affected; the 1972 funding level was down by 40 percent since 1967, the year of its maximum funding.

R&D FUNDING BY UNIVERSITIES AND COLLEGES

These institutions together with other nonprofit organizations provide the remaining 5 percent of total national expenditures for R&D, with the universities accounting for 4 percent. University expenditures are concentrated in research, with basic research accounting for 78 percent of expenditures and applied research 20 percent in 1972. This pattern of funding distribution persisted with only minor changes throughout the 1961-72 period.[7]

Research expenditures reported by universities and colleges come from various non-Federal sources, including State governments, industries, and foundations as well as from university funds. In 1970 the separately budgeted research expenditures from non-Federal sources were distributed among major fields of science as follows:

	Percent
Life Sciences	47
Social Sciences	16
Engineering	12
Physical Sciences	9
Mathematics	5
Environmental Sciences	4
Psychology	3

There was little change in this distribution over the 1964-70 period for which data are available. (Academic research is treated more extensively elsewhere in this report.)

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[5] Projections are based on a National Science Foundation survey in 1972 of 50 of the largest corporations in the United States.

[6] National Science Foundation, *Research and Development in Industry 1970*, NSF 72-309.

[7] National Science Foundation, *National Patterns of R&D Resources 1953-72*, NSF 72-300.

Basic Research

Basic Research

Indicators of the state of basic research presented in this chapter are confined largely to the resources expended for such activity. These include indicators of the national expenditures for fundamental research; levels of basic research in universities and colleges, Federal laboratories, and industry; and trends in expenditures among scientific disciplines.

Input measures such as these provide only an indication of the level of basic research activity, not its effectiveness or productivity. A research effort, moreover, may be regarded as either basic or applied, depending upon whether the perspective of the sponsor of the reserach or that of the organization performing it is taken as the point of reference. Additional uncertainties are presented by differing treatments of costs associated with basic research. For example, the construction costs of large government-financed research facilities such as the National Accelerator Laboratory are not included as basic research expenditures, whereas NASA space probes include the costs of spacecraft and launch vehicles. To compound the difficulty of comparability, industrial firms include in their reported expenditures for basic research an annual depreciation cost of the facilities involved, whereas Federal laboratories do not include such costs.

INDICATOR HIGHLIGHTS

- **Basic research expenditures, in current dollars, rose continually during the period 1960-72, although the rate of growth slowed after 1968; in constant 1958 dollars, basic research spending in 1972 was approximately equal to the 1967 level, and some 6 percent lower than the peak year of 1968.**
- **The 1968-72 decline in constant 1958 dollar expenditures for basic research was least in universities and colleges (3 percent) and largest in industry (14 percent).**
- **The share of total basic research expenditures used by the different sectors changed significantly between 1960-72; the universities' share increased from 43 to 57 percent, while industry's share fell from 28 to 16 percent.**
- **The Federal Government provided 62 percent of the total 1972 funds for basic research in the United States, as compared with 52 percent in 1960; basic research funds provided by universities and colleges rose from some 16 percent of the total in the early and mid-1960's to approximately 20 percent in 1972.**
- **Basic research funds (in current dollars) provided by the Federal Government increased rapidly between 1960-68 but slowed to small annual increments thereafter; in constant 1958 dollars, however, a 10-percent decline in funding occurred between 1968-72, which included a 16-percent reduction in basic research funds to industry, a 10-percent reduction to universities and colleges, and a 7-percent decline for nonprofit institutions.**
- **Total expenditures (Federal and non-Federal) for basic research in universities and colleges increased in current dollars between 1968-72 for 8 of 10 major fields.[1] In constant 1961 dollars, expenditures increased for the biological sciences, clinical medicine, social sciences, and psychology and decreased for astronomy, physics, chemistry, and engineering.**
- **Federal funds (in current dollars) for basic research in universities and colleges increased between 1968-72 for all fields except astronomy and physics; in constant 1961 dollars, funds declined from the 1968 level in all fields except the environmental sciences and psychology.**

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[1] The scientific fields included were astronomy, biological sciences, chemistry, clinical medicine, engineering, environmental sciences, mathematical and computer sciences, physics, psychology, and the social sciences.

☐ Total funds for basic and applied research per scientist and engineer in Ph.D.-granting institutions declined 15 percent between 1968-72 in constant 1961 dollars, as a result of reduced Federal expenditures and continued growth of faculty; research funds per scientist and engineer decreased in all fields except the social sciences, with the largest declines occurring in physics (32 percent), clinical medicine (21 percent), and engineering (17 percent).

☐ The proportion of Ph.D. scientists in universities and colleges engaged in basic research supported by the Federal Government declined from 69 percent in 1964 and 1966 to 57 percent in 1970.

☐ Federal support for young investigators (those holding a Ph.D. less than seven years) in universities and colleges declined to a greater extent than support for senior investigators; the proportion of young investigators supported fell from 65 percent in 1964 to 50 percent in 1970, versus 73 percent to 63 percent for senior investigators.

☐ Government expenditures for basic research in Federal laboratories declined by almost 20 percent in constant 1961 dollars between 1970-72, with the largest reductions occurring in laboratories funded by the National Aeronautics and Space Administration and the Department of Health, Education, and Welfare.

☐ Current dollar expenditures for industry-funded basic research, which accounts for only a small fraction of all such research, increased until 1966 and remained at nearly that level until 1972 when they again increased; in 1958 constant dollars, however, expenditures declined by some 17 percent between 1966-72.

☐ Basic research in industry is concentrated in the fields of chemistry and engineering, followed by physics and the life sciences. Recent declines in constant 1958 dollar expenditures for basic research were largest in the areas of physics and chemistry.

■ Basic research is that portion of the total R&D effort whose primary aim is extending the fundamental understanding of man and nature. The strategy of basic research is determined primarily by the structure of science itself which indicates opportunities and possible directions for advancing knowledge. Although potential applications often underlie and ultimately justify support for basic research, such research must emanate from the conceptual structure of science itself.

While the relationships between basic research and eventual applications are often complex and may involve a considerable time interval for realization, there is no doubt that modern technology is increasingly dependent upon the fundamental knowledge base. Basic science, moreover, provides a pool of knowledge and understanding which helps in determining the most efficient strategy for applied research and development, and also serves as a source of ideas for new applications and for attacking social problems as well. The contributions of basic research to the quality and variety of our lives are innumerable, and include:

- **Genetics,** which advanced the development of hybrid grains, stock breeding, vaccines, and medical diagnostic techniques;
- **Chemistry,** which produced polyester fibers, pharmaceuticals, petroleum refining, and pesticides;
- **Physics,** which led to the development of nuclear power generation, transistors, and radioisotope tracers;
- **Electronics,** which developed radar, magnetic tape recording, heart pacemakers, and biomedical recording techniques;
- **Mathematics,** which helped in the development of computers, multivariate analysis techniques, systems analysis, and simulation models; and
- **Social Sciences,** which devised polling and survey methods, national income and product accounting, cost-benefit analysis, aptitude testing, and economic input-output models.

Finally, basic research is an essential part of education. It is not only an integral element of advanced education in the sciences and engineering but its findings constitute the objective knowledge of the physical and social world which is part of the education of the population as a whole.

Whether for educational and cultural purposes, for technological and social reasons, or for the sheer intellectual understanding basic research provides, the health and vitality of such research is a matter of national significance.

RESOURCES FOR BASIC RESEARCH

Expenditures by Performer

Expenditures for the support of basic research are used here as an indicator of the level of this activity. Figure 21 shows total expenditures, by year, for basic research in the United States and the portions of the total performed by the various sectors of the research community. In terms of current dollars, expenditures increased progressively during the 1960-72 period, although the rate of increase slowed after 1968.

Instead of the continuous rise in basic research expenditures depicted by the current dollar curve, expenditures expressed in constant dollars peaked in 1968 and declined almost continuously thereafter (figure 21). The net result is that 1972 expenditures were almost equivalent (in constant dollars) to the 1967 level and some 6 percent smaller than the peak year of 1968.

The small growth in current dollar expenditures after 1968 was not sufficient to offset the effects of inflation, in any of the five sectors. The 1968-72 decline in constant dollar expenditures for basic research was largest in industry (14 percent) and smallest in universities and colleges (3 percent).

The share of the total basic research expenditures used by the different sectors changed significantly between 1960-72. The universities increased their share from 43 to 57 percent, while industry's share fell from 28 to 16 percent and that of the nonprofit institutions declined from 9 to 6 percent. The share of the Federal in-house programs rose from 12 percent in 1960 to 14 percent in 1972, whereas the Federally Funded Research and Development Centers' (FFRDC) share remained approximately constant at about 7 percent.

Expenditures by Sources

It should be noted that for three of the sectors reported—the Federal Government, universities and colleges, and other nonprofit institutions—the definition of basic research stresses that it is directed toward increases of knowledge in science with " . . . the primary aim of the investigator being . . . a fuller knowledge or understanding of the subject under study, rather than a practical application thereof."[2] For the industrial sector, in order to take account of an individual industrial company's commercial goals, the definition is modified to indicate that basic research projects represent "original investigations for the advancement of scientific knowledge—which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company."[2]

Using these definitions, the total funds for basic research supplied by these sectors are shown for the period 1960-72 in current and in constant dollars in figure 21. It can be seen that the Federal funds increased rapidly during the 1960-68 period, but then slowed to small annual increases, which convert to decreases in constant dollars.

As calculated from these data, the Federal Government provided 62 percent of the total funds for all U.S. basic research conducted in 1972; this proportion has changed little since the mid-60's after rising from a level of 52 percent in 1960. Basic research funds provided by universities and colleges rose from some 16 percent of the total in the early and mid-1960's to approximately 20 percent in 1972 (figure 21). The largest proportional change occurred in industry-funded basic research, the share for which declined steadily from a high of 25 percent in 1960 to only 13 percent in 1972.

Federal Expenditures. Basic research expenditures by the Federal Government are shown in figure 22 for the five performing sectors. Federal support of basic research in universities de-

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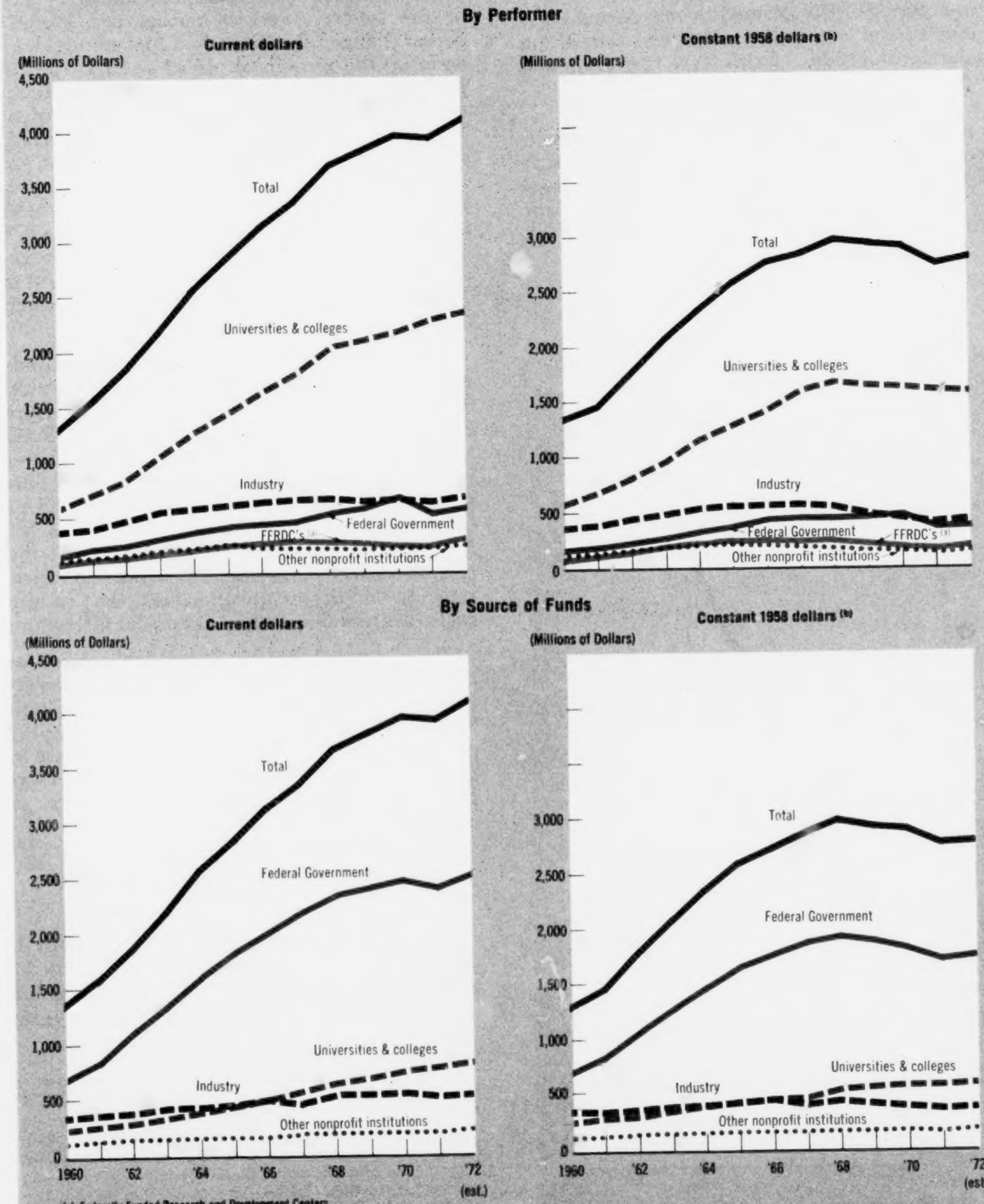
[2] National Science Foundation, *National Patterns of R&D Resources 1953-72,* (NSF 72-300).

Figure 21
Basic Research Expenditures, 1960-72



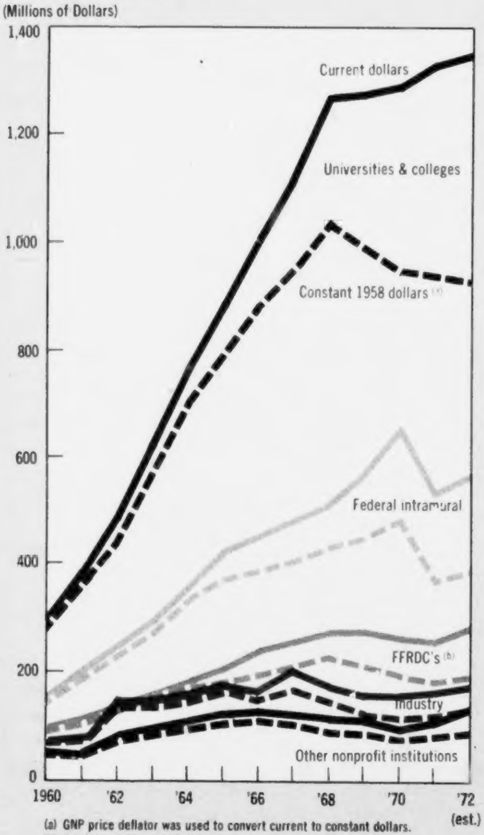
(a) Federally Funded Research and Development Centers.
(b) GNP price deflator was used to convert current to constant dollars.
SOURCE: National Science Foundation.

clined by some 10 percent, in constant dollars, for the period 1968-72, while Federal support of its own basic research decreased 6 percent in the same period. Also affected in this period were industry and nonprofit institutions where the reductions in Federal funds were 16 percent and 7 percent, respectively.

Six agencies of the Government supply almost 95 percent of all Federal funds for basic research (figure 23). About 50 percent is provided by two of them—the National Aeronautics and Space Administration (NASA) (31 percent) and the Department of Health, Education, and Welfare (HEW) (20 percent). The proportion of total Federal funds for basic research provided by each of the several agencies during the 1960-72 period changed significantly. Chief among these were (a) the growth of NASA's share from 16 percent in 1960 to 31 percent in 1972; (b) the decline of the share of the Defense Department (DOD) from 28 to 11 percent—a shift which occurred concurrently with the growth of NASA's share; and (c) the decline in the Atomic Energy Commission's (AEC) share from 17 to 11 percent. The 1967 decline in basic research obligations for DOD and AEC appear to account largely for the reduced rate of growth in overall Federal expenditures for basic research which occurred in 1968.

Figure 22

Federal Expenditures for Basic Research, by Performer, 1960-72



(a) GNP price deflator was used to convert current to constant dollars.
(b) Administered by universities.

SOURCE: National Science Foundation.

As noted earlier, NASA provides more funds for basic research than any other Federal agency. The entire activities of that agency, however, are considered as either R&D or support of R&D (outlays for construction of facilities). The latter now comprises less than 2 percent of total outlays, and has never exceeded 14 percent. NASA's obligations for basic research (as well as for applied research and development) include the related costs of spacecraft, launch vehicles, tracking and data acquisition, and the pro rata costs of ground operations and administration.

The estimated FY 1973 Federal obligations (in current dollars) for basic research indicate an increase of almost 9 percent over the obligation level of FY 1972, which in turn represented a 12-percent increase over FY 1971.[3] The increase in basic research expenditures in FY 1973 is expected to be less than obligations.

BASIC RESEARCH IN UNIVERSITIES AND COLLEGES

Estimated expenditures for basic research in universities and colleges are shown in figure 24 in both current and 1961 dollars, for selected scientific fields.[4] (Expenditure data for years

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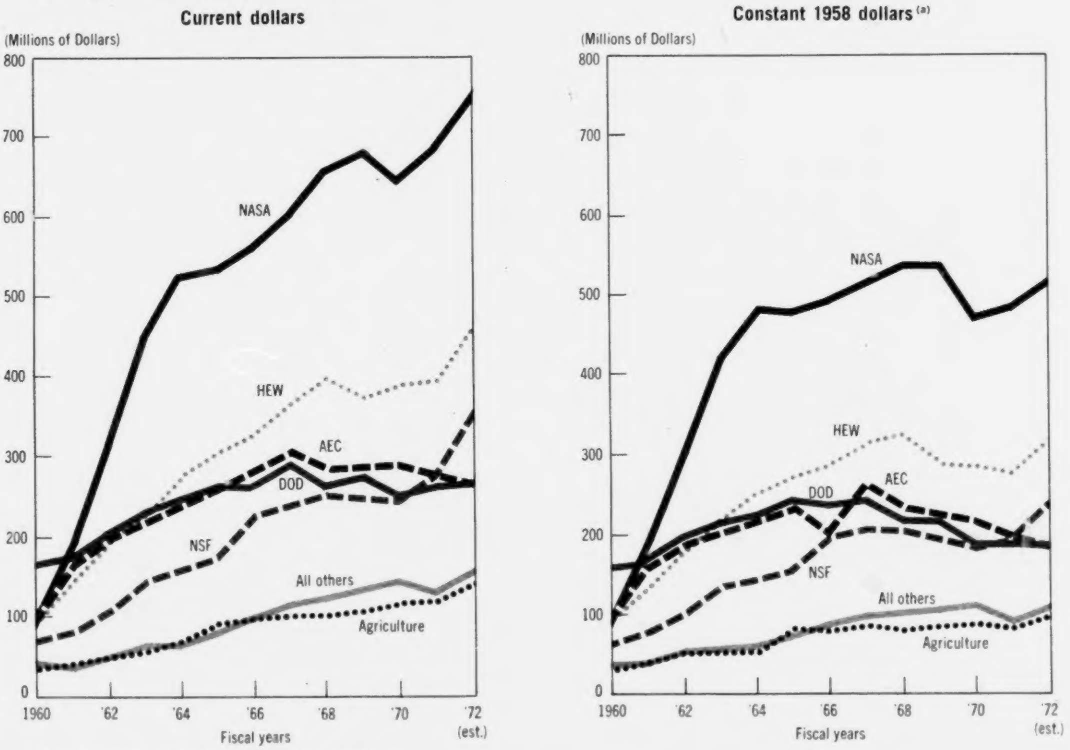
[3] National Science Foundation, *Federal Funds for Research, Development and other Scientific Activities*, Vol. XXI NSF 72-317. In press.

[4] The recently developed Academic R&D Price Index (*A Price Index for Deflation of Academic R&D Expenditures*, National Science Foundation, NSF 72-310) was used to convert current to constant dollars. The conversion, it should be noted, may not fully reflect increases in indirect costs which reduce the actual level of research; these costs appear to have increased at an even faster rate than direct expenses, as shown elsewhere in this report.

Figure 23

Federal Obligations for Basic Research, by Supporting Agency, FY 1960-72


Current dollars

Constant 1958 dollars [a]

[a] GNP price deflator was used to convert current to constant dollars.

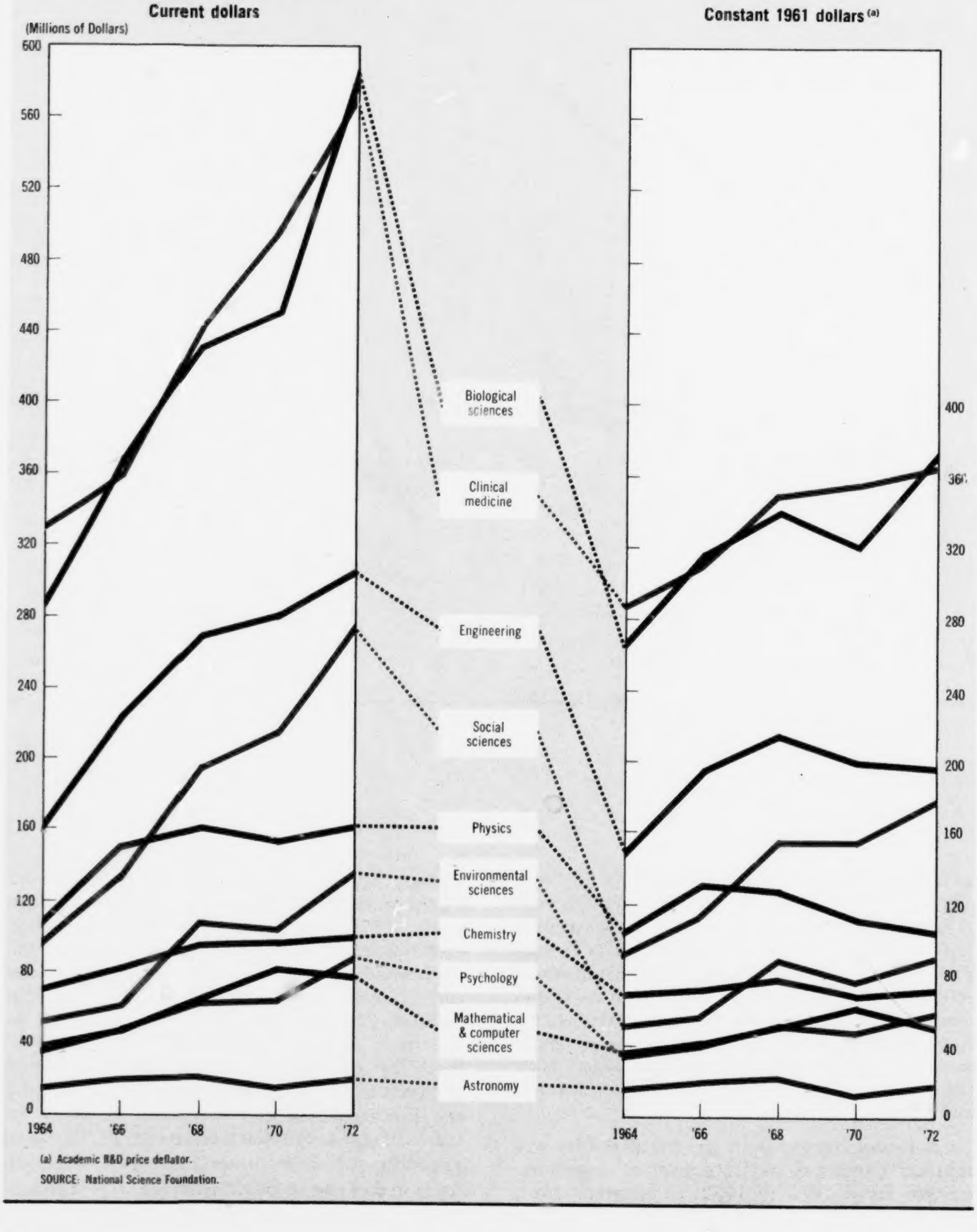
SOURCE: National Science Foundation.

prior to 1964 are not available.) The 10 fields represented in figure 24 form three groupings in respect to the relative growth of expenditures between 1964-72: fields recording the largest growth were the social sciences, environmental sciences, and psychology; fields with an intermediate level of growth were biological sciences, mathematical and computer sciences, engineering, and clinical medicine; and those with the smallest growth were chemistry, astronomy, and physics.

Current dollar expenditures for all fields—except mathematical and computer sciences—increased from 1970 to 1972. In constant 1961 dollars, however, expenditures for 1972 declined or remained essentially unchanged from their 1970 level in physics, chemistry, astronomy, and engineering as well as in the mathematical and computer sciences. The declines were due principally to reductions in Federal expenditures for basic research, as shown in figure 25. Current dollar expenditures by the Federal Government increased between 1970-72 for all fields except physics and the mathematical and computer sciences. In terms of constant dollars, however, 1972 Federal expenditures were lower than 1970 expenditures in 6 of the 10 fields, with the largest reduc-

Figure 24

Estimated Expenditures for Basic Research in Universities and Colleges, by Field of Science, 1964-72

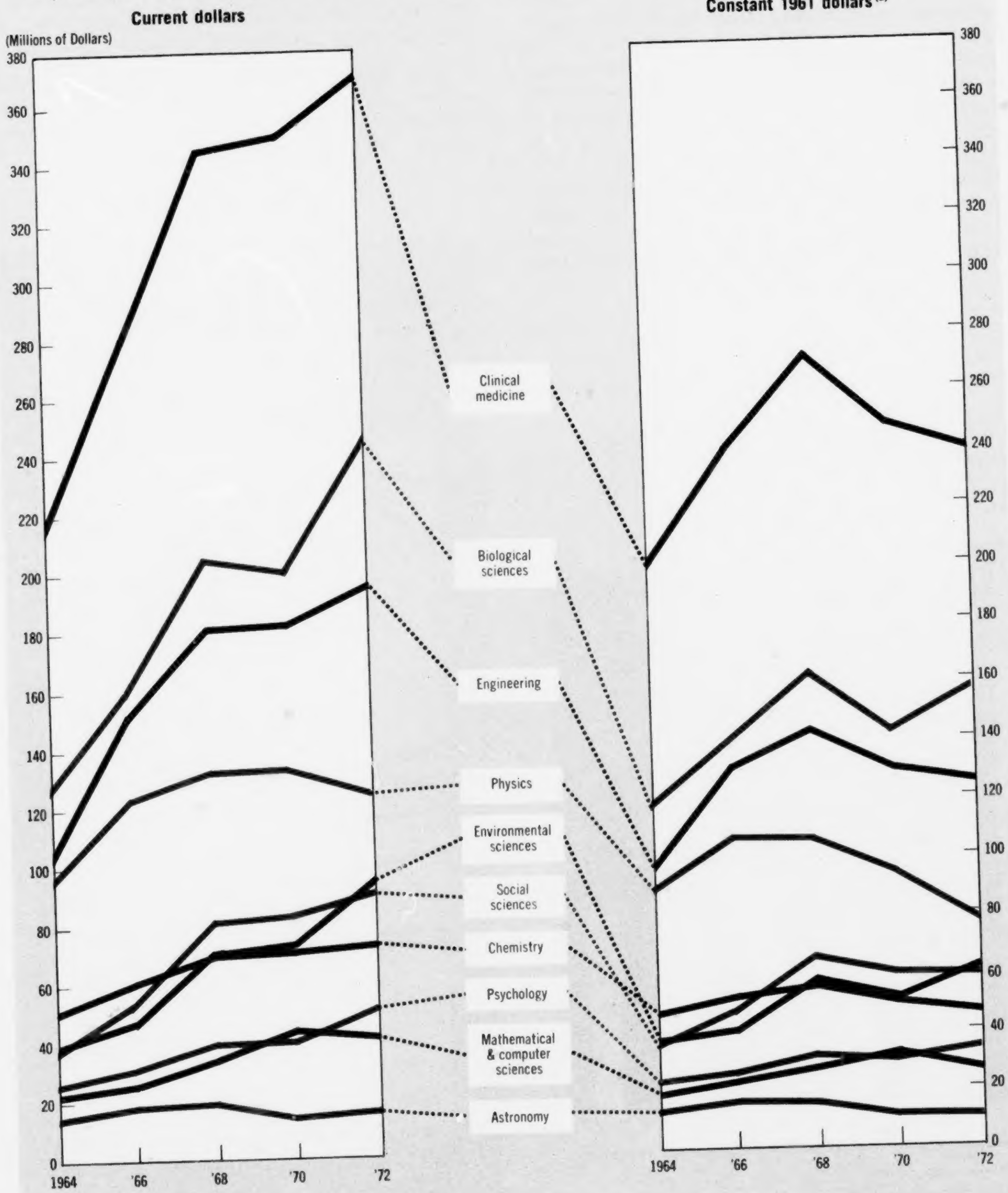


(a) Academic R&D price deflator.

SOURCE: National Science Foundation.

Figure 25

Estimated Federal Expenditures for Basic Research in Universities and Colleges, by Field of Science, 1964-72



(a) Academic R&D price deflator.

SOURCE: National Science Foundation.

tion (16 percent) occurring in physics. Federal funding for the latter field decreased by some 25 percent between 1968-72.

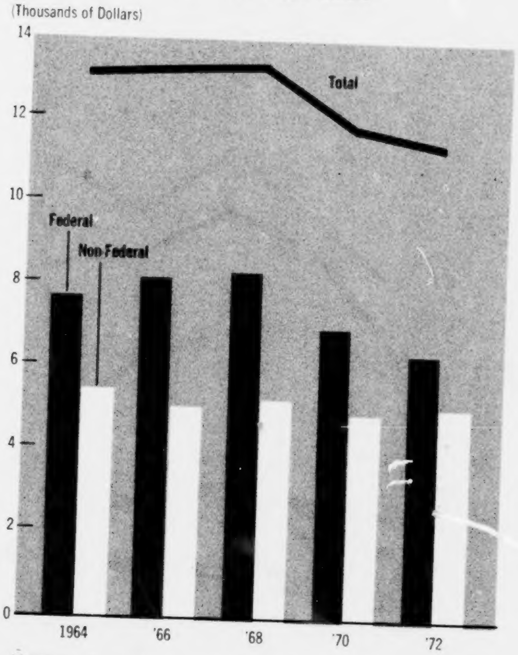
In view of the declining research expenditures coupled with increased costs of performing research and a larger faculty body, some change in the involvement of academic staff in research is inevitable. One aspect of this change is indicated in figure 26, which presents the funds for applied and basic research per scientist and engineer (excluding graduate students) in Ph.D.-granting institutions. (These institutions accounted for 96 percent of all academic research in 1972.) The 1972 level of such funds was 15 percent lower than in 1968, in terms of 1961 dollars. This reduction is attributable to the declining level of Federal funding between 1968-72, coupled with the increasing number of scientists and engineers in these institutions; Federal research funds per scientist and engineer declined by 24 percent during the 1968-72 period, in contrast to the relatively unchanged level of support from non-Federal sources.

The individual fields were affected somewhat differently by the combined changes in the levels of funding and scientific and engineering manpower, as shown in figure 27. (The fields of

Figure 26

Federal and Non-Federal Research Funds per Scientist and Engineer in Doctorate-Granting Institutions,[a] 1964-72

Constant 1961 dollars[b]



(a) Includes all scientists and engineers (full-time-equivalent basis) employed in universities.

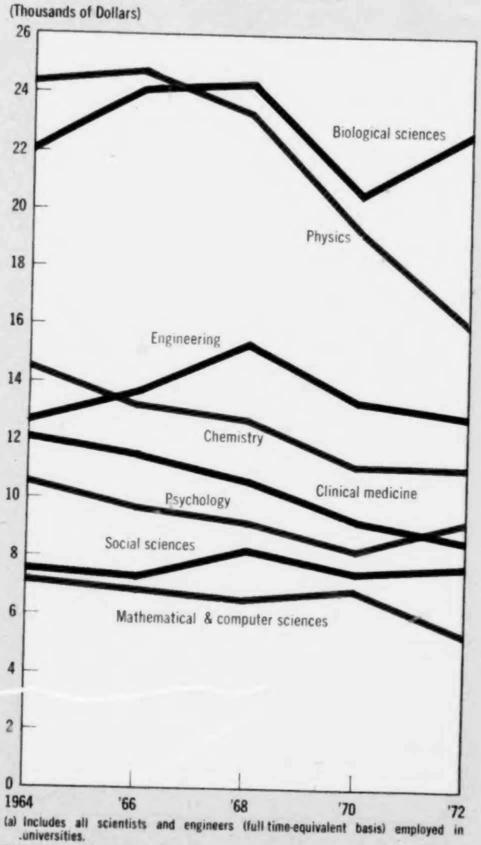
(b) Academic R&D price deflator.

SOURCE: National Science Foundation.

Figure 27

Research Expenditures per Scientist and Engineer[a] in Doctorate-Granting Institutions, by Selected Field of Science, 1964-72

Constant 1961 dollars[b]



(a) Includes all scientists and engineers (full time-equivalent basis) employed in universities.

(b) Academic R&D price deflator.

SOURCE: National Science Foundation.

astronomy and environmental sciences are not included because of the lack of acceptably reliable data.)[5] Although the overall trend is a reduction in the level of research support per scientist and engineer, the funds for some fields declined much more than others. Research funds per physicist, for example, declined by 35 percent between 1966-72, while funds per social scientist changed little even though the number of such scientists increased rapidly.

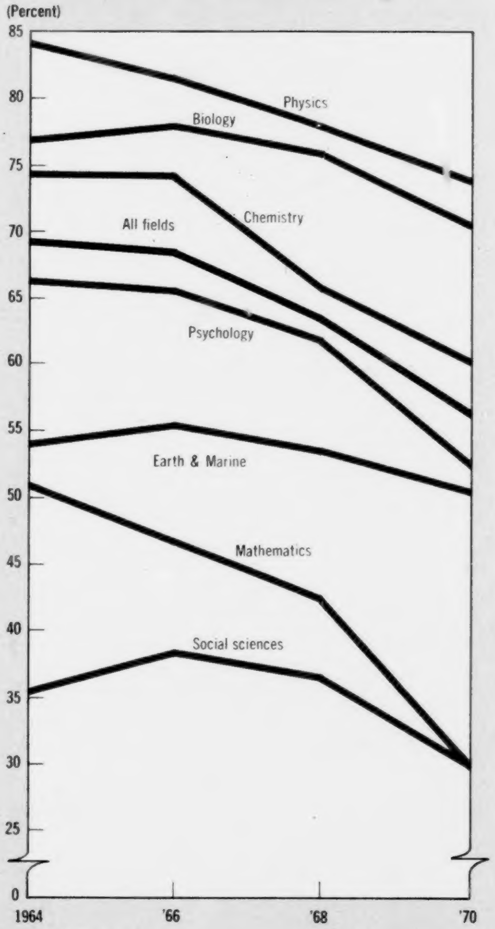
The number of scientists and engineers engaged in research and development (on a full-time-equivalent basis) declined slightly between 1969 and 1971. This may represent a reduction in the average time devoted to R&D by the staff as a whole and/or a reduction in the number of staff engaged in any R&D at all. The available data are not sufficient to resolve this ambiguity. Moreover, it is generally difficult to accurately separate the time devoted to research from other academic activities.

The proportion of the Ph.D. science staff in these institutions receiving Federal support and engaged in basic research is shown in figure 28 for several scientific fields.[6] The figure indicates that the proportion of Ph.D. academic staff who were wholly or in part supported by the Federal Government and devoted some portion of their time to basic research[7] was 57 percent in 1970, down from 69 percent in 1964 and 1966. The largest decreases were in mathematics, chemistry, psychology, and physics.

Research support for young investigators[8] is of particular interest as an indicator, since the progress and quality of future research and innovation depend increasingly on individuals from this group. Federal support for young investigators engaged in basic research decreased in recent years, falling from 64 percent in 1964 to 50 percent in 1970 (figure 29). While the proportion of senior investigators receiving such support also declined, the reduction was not so large as for the young investigators. Moreover, proportionally fewer young researchers obtained Federal support in certain fields (as indicated in figure 30), especially in mathematics, social sciences, and psychology, where the ratio of young to senior basic re-

Figure 28

Proportion of Ph.D. Academic Staff in Science Receiving Federal Support and Engaged in Basic Research, by Field, 1964-70



SOURCE: National Science Foundation.

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[5] It should be noted that the considerable variation in the level of funding among fields reflects, among other factors, differences in the cost of research associated with each field; some fields, for example, require extensive equipment for research while others require little.

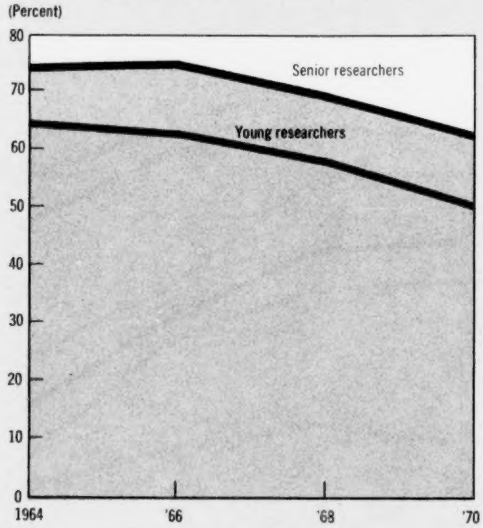
[6] Included are Ph.D.'s employed by academic institutions who indicated that basic research was their first or second work activity. In 1970, these persons accounted for about 75 percent of all academic Ph.D.'s.

[7] These data are based on responses to the National Register of Scientific and Technical Personnel for the years 1964, 1966, 1968, and 1970. It is estimated that the responses account for approximately 80 percent of the Ph.D. scientists employed by universities and colleges.

[8] Defined as those employed by colleges and universities who have held the Ph.D. less than seven years and who reported their primary or secondary work activity as basic research.

Figure 29

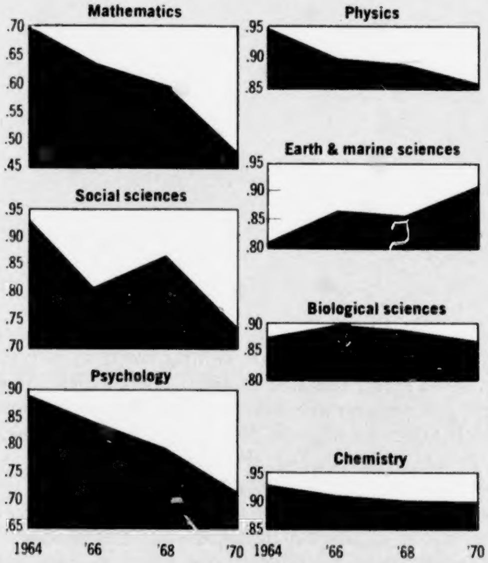
Proportion of Young and Senior Ph.D. Academic Staff in Science Receiving Federal Support and Engaged in Basic Research, 1964-70



SOURCE: National Science Foundation.

Figure 30

Ratio of Young to Senior Ph.D. Academic Staff Receiving Federal Support and Engaged in Basic Research, by Field, 1964-70



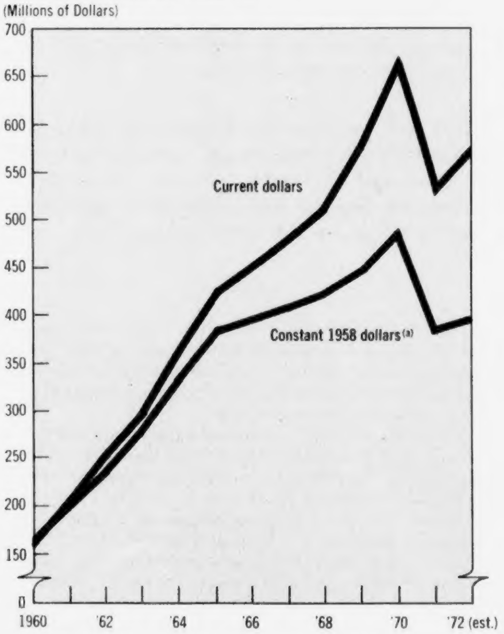
SOURCE: National Science Foundation.

searchers declined between 28 and 18 percent. In other fields, the decline was less than 10 percent.

Research at universities cannot be characterized completely by the parameters discussed so far, namely, manpower and funds. The state of basic research in universities must also be related to the health of the institutions themselves. This is especially significant since the universities have traditionally shared the cost of research in their laboratories. The symbiosis between universities and basic research makes the overall financial situation of the universities a cause for concern in assessing the state of science, especially its future prospects. While research support will not by itself solve the financial problems of universities, its decline has contributed to their difficulties, in that research grants often carry a number of continuing university costs of a long-term nature, such as building maintenance, administration, and a portion of long-term salary commitments to faculty.

Figure 31

Federal Expenditures for Intramural Basic Science, 1960-72



(a) GNP price deflator was used to convert current to constant dollars.

SOURCE: National Science Foundation.

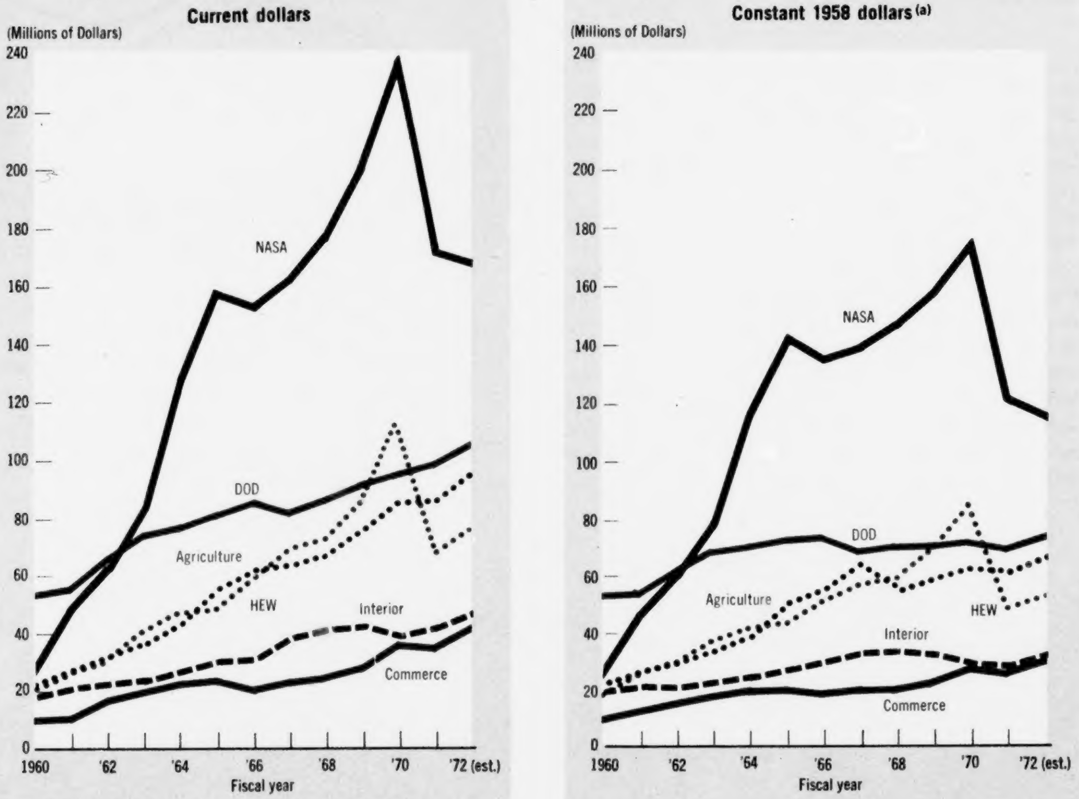
BASIC RESEARCH IN FEDERAL LABORATORIES

Total Federal expenditures for in-house basic research increased over the 1960-72 period in terms of both current (259 percent) and constant (154 percent) dollars (figure 31). However, during the 1970-72 period, expenditures decreased by 13 percent in terms of current dollars and by 19 percent when expressed in constant 1958 dollars. The declines occurred principally in laboratories funded by the National Aeronautics and Space Administration (NASA) and the Department of Health, Education, and Welfare (HEW). In 1972, the in-house basic research effort represented 23 percent of all Federal expenditures for basic research. Similarly, it accounted for 14 percent of the total expenditures for basic research in 1972, compared with 12 percent in 1960.

Data are not available for segregating the activities by field of science, but obligation data are presented in figure 32 for the Federal agencies which support the bulk of in-house basic research. In 1972, the total Federal obligations for in-house R&D were divided among the agencies as follows: NASA (29 percent), Department of Defense (18 percent), Agriculture (17 percent), HEW (13 percent), Interior (8 percent), and Commerce (7 percent).

Figure 32

Federal Expenditures for Intramural Basic Research, by Selected Agency, 1960-72



(a) GNP price deflator was used to convert current to constant dollars.

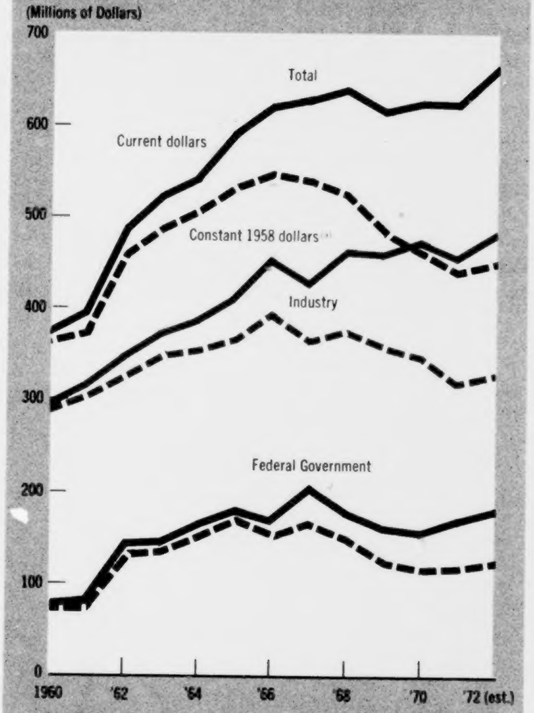
SOURCE: National Science Foundation.

BASIC RESEARCH IN INDUSTRY

Expenditures for basic research in industry are shown in figure 33. In current dollars, total basic research expenditures increased by 3 percent over the period 1968-72; in constant 1958 dollars, the decline in overall funding was 14 percent between 1968-72, which included a 16-percent reduction in Federal funding and a 13-percent decline in industrial support.

Some 75 percent of all industrial basic research was performed by four industries in 1970: chemicals and allied products (36 percent); electrical equipment and communication (24 percent); aircraft and missiles (10 percent); and petroleum refining and extraction (5 percent).[9] There is considerable difference among these industries in the percentage of total R&D which is devoted to basic research. The chemical industry in 1970 devoted 12 percent of its R&D to basic research, as compared with 3 percent for the electrical equipment industry, 4 percent for the petroleum industry, and 1 percent for the aircraft and missiles industry.

Figure 33
Industrial Basic Research Expenditures, by Source, 1960-72



(a) GNP price deflator was used to convert current to constant dollars.
SOURCE: National Science Foundation.

The principal fields of science in which basic research is performed are shown in figure 34 for the 1967-70 period, the only years for which such data are available. As shown, the fields of chemistry and engineering receive almost 65 percent of all basic research expenditures. A major change over the 4-year period was the reduction of basic research in the fields of physics and astronomy; although the available data do not permit the separation of these two fields, expenditures for physics presumably accounted for most of the joint activities of these fields. In respect to the industries involved, basic research performed by the chemical industry accounted for almost 80 percent of the life science and 46 percent of physical science expenditures of all industries. The bulk of engineering research expenditures were by electrical equipment industries (41 percent) and aircraft and missiles industries (21 percent).

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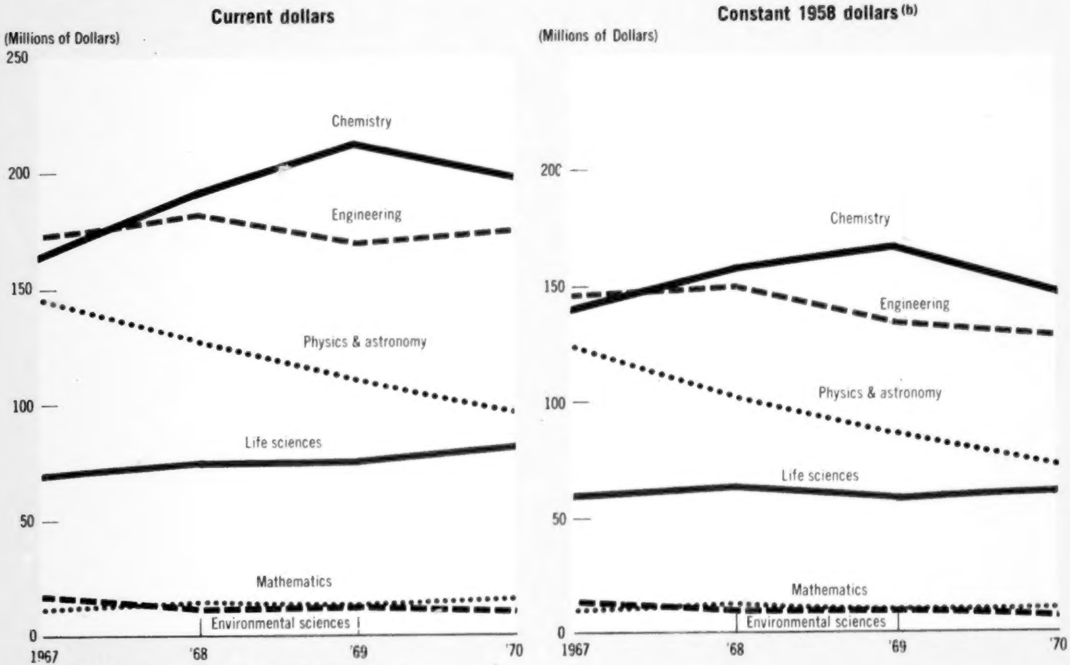
[9] National Science Foundation, *Research and Development in Industry, 1970*, NSF 72-309.

Figure 34

Industrial Basic Research Expenditures, by Field of Science, 1967-70[a]



(a) GNP price deflator was used to convert current to constant dollars.

SOURCE: National Science Foundation.

Science and Engineering Personnel

Science and Engineering Personnel

Indicators in this section chart the growth of the national pool of scientists and engineers; present trends in the utilization of such personnel; provide data on undergraduate and graduate enrollments and financial support; depict growth patterns in the production of scientists and engineers; and measure changes in their employment level.

Available data and present methodology did not permit the development of indicators of the quality and productivity of the Nation's scientists and engineers. For the same reasons, it was not possible to devise reliable indices of the future demand for and supply of such personnel for inclusion in the present report. Improvements in both data (e.g., better information on the utilization of scientists and engineers in non-academic, non-R&D activities and the role of immigration and emigration of personnel) and methodology (e.g., better techniques for predicting the future state of the economy and for anticipating the emergence of national problems requiring the services of scientists and engineers) are required for more reliable forecasts of the supply-demand situation. As methodologies and data series used in projections are improved, indicators of supply-demand relationships will be included in future reports of this series.

INDICATOR HIGHLIGHTS

- The total pool of active scientists and engineers in the United States grew by about 50 percent from 1960 to 1971, rising to some 1,750,000. The number with doctorates doubled during the period, reaching 10 percent of the total.

- Scientists and engineers comprised an increasingly larger proportion of total civilian employment over the last two decades, although the extent of the increase in the 1960's (167 to 210 per 10,000 workers) was less than that during the 1950's (93 to 167 per 10,000 workers).

- The proportion of natural scientists and engineers engaged in R&D increased to 37 percent between 1960-64, but declined steadily thereafter. This downward trend was more pronounced among academic than industrial scientists and engineers, and reflects the growth in faculty needed for teaching, as well as the leveling off of R&D funds.

- Between 1968 and 1970 the number of natural scientists and engineers in industrial R&D declined to the 1967 level, the first such decline during the 1960's.

- The distribution of scientists and engineers among major types of employers changed between 1960-70, with the proportion in industry declining from 74 to 66 percent and the fraction in universities and colleges rising from 11 to 18 percent.

- Total enrollments in high school courses of social sciences, natural sciences, and mathematics grew faster than total secondary enrollments between 1960-70, with the largest increases occurring in psychology and economics and the smallest in physics, chemistry, and mathematics. Physics was the only field in which the proportional growth was less than the increase in total enrollments.

- The number of undergraduate students at the junior-year level who declared majors in physics, engineering, and chemistry declined between 1970-71, whereas the number declaring majors in the applied social sciences and professional life sciences increased significantly.

- Graduate enrollments (full-time and part-time combined) in science doctorate departments declined by almost 4 percent between 1969 and 1971, the first such absolute decrease in the 1960's. Such enrollments in science and engineering, as a percent of total graduate enrollments, declined steadily from 38 percent in 1963 to 31 percent in 1970.

- The number of full-time graduate students in science and engineering receiving Federal support declined by 15 percent between 1969-71, while those depending on self-support increased by 19 percent from a lower base.
- Annual awards of bachelor's level degrees in science and engineering increased by a factor of 2.2 over the 1959-71 period, with the largest gains in the social sciences (4.1 times) and the smallest in the physical sciences (1.3) and engineering (1.2). First degrees in science and engineering, as a fraction of all bachelor's level degrees, remained essentially constant at 30 percent, due in large part to the rapid growth of social science degrees.
- Annual awards of master's degrees in science and engineering rose by a factor of 2.5 over the 1959-71 period, with the largest gains in mathematical sciences (3.8) and social sciences (3.1) and the smallest in the physical sciences (1.9). Science and engineering master's degrees, as a fraction of all master's degrees, declined from a high of 30 percent to 22 percent in 1970-71, with the largest proportional declines occurring in engineering and the physical sciences.
- Annual awards of Ph.D. degrees in science and engineering rose by a factor of 3.0 over the 1959-71 period, with the largest gains in engineering (4.6) and mathematical sciences (4.4) and the smallest in the physical sciences (2.4). Science and engineering Ph.D. degrees, as a fraction of all Ph.D. degrees, declined from 62 percent in the mid-1960's to 58 percent in 1970-71, with the largest proportional declines in the physical sciences.
- During the last decade, awards of science and engineering doctorates, in terms of location of high school graduation, became more evenly distributed among geographic regions of the United States. The proportion, however, is almost 50 percent lower in the South Atlantic and East South Central regions than in other areas of the country.
- Unemployment rates for scientists and engineers rose after 1969, reaching 2.6 and 2.9 percent, respectively, by early 1971. These rates—which were less than half those reported for all workers—declined to early 1970 levels by late 1972.

■ Substantial changes in the demand for scientists and engineers, which may be produced by factors such as a redirection in Federal funding or the state of the national economy, may occur over periods of from two or three years. But because scientists and engineers require training extending over several years, serious imbalances of supply and demand, inadequacies of training, maldistributions among areas of competence, and similar problems may be corrected only over a longer five- to ten-year span. Therefore, the extended time and high cost involved in producing scientists and engineers require that careful, continuous attention be given to the nature, quality, and applicability of their professional training.

CURRENT POOL OF SCIENTISTS AND ENGINEERS[1]

Magnitude

The total pool of active scientists and engineers in the United States grew by some 50 percent between 1960 and 1970, rising from about 1,170,000 to more than 1,700,000 (figure 35). (It is estimated that by 1971 this number had further increased to about 1,750,000.) This rapid growth was due to an increase in science and engineering degree holders and to the "upgrading" of nondegree personnel, principally engineers. From 1960 to 1970 scientists and engineers with doctoral degrees increased from 90,000 to over 170,000. The number of engineering doctorates tripled during this period, while science doctorates increased by about 75 percent. As a result, the percentage of scientists with doctoral degrees remained almost constant during the past decade, while the percent-

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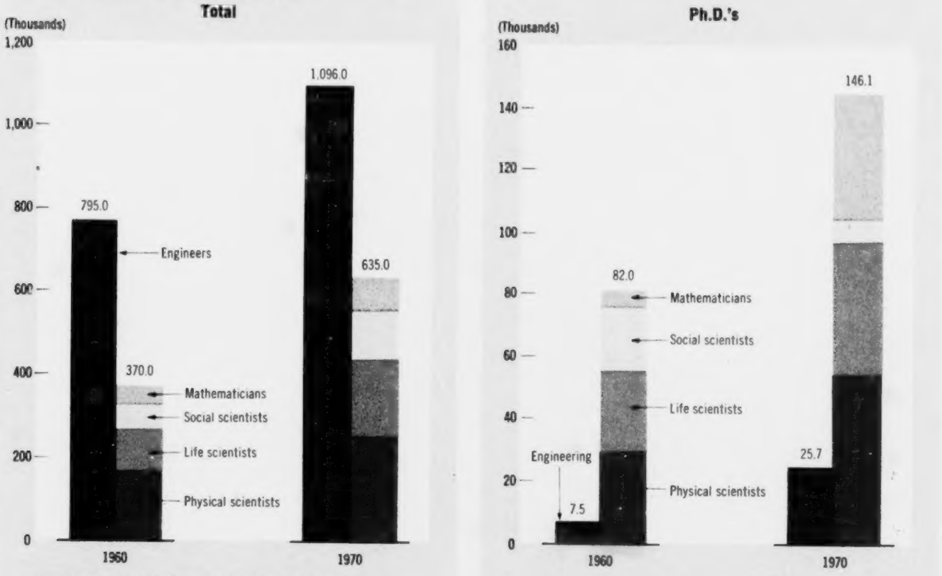
[1] Information on the current numbers, types of employer, employment activities, etc., of scientists and engineers must be assembled from numerous data sources. Since not all of these are updated annually, it is possible to develop the latest complete picture only for 1970, even though many pieces of this mosaic are already available for 1971. Unless otherwise specified, scientists and engineers include the natural scientists (including mathematicians), social scientists, and engineers.

Figure 35

Distribution of Scientists and Engineers, by Broad Field, 1960 and 1970



SOURCE: Bureau of Labor Statistics and National Science Foundation.

age of engineers with doctorates doubled—from a low base of less than one percent. In absolute terms more than four times as many science (90,000) as engineering (22,000) doctorates were awarded during this period. Thus, science doctorates as a percentage of all scientists continued to be a much larger ratio than engineering doctorates as a percentage of all engineers. All told, more than 185,000 scientists and engineers with doctorates were working in the United States by 1971.

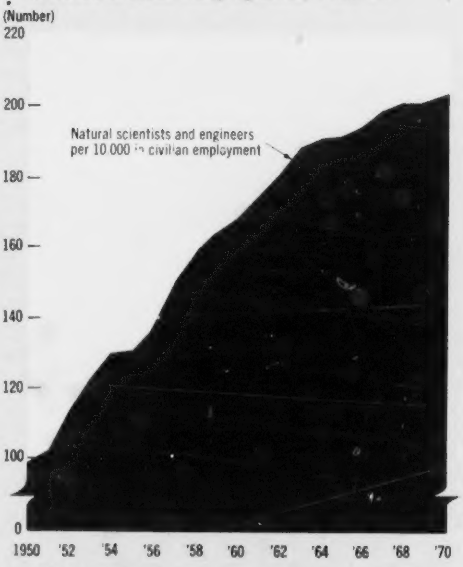
Another measure of growth is the ratio of the number of natural scientists and engineers to total civilian employment (figure 36). This ratio increased from 93 per 10,000 working adults in 1950 to 167 in 1960 and then to 210 in 1970. Thus, the extent of the growth was greater in the 1950's than in the 1960's.

R&D and Non-R&D Activities

The relative changes during the last decade in the numbers of natural scientists and engineers engaged in R&D—as well as in the percentages of all natural scientists and engineers in R&D—have been substantial (figure 37). In

Figure 36

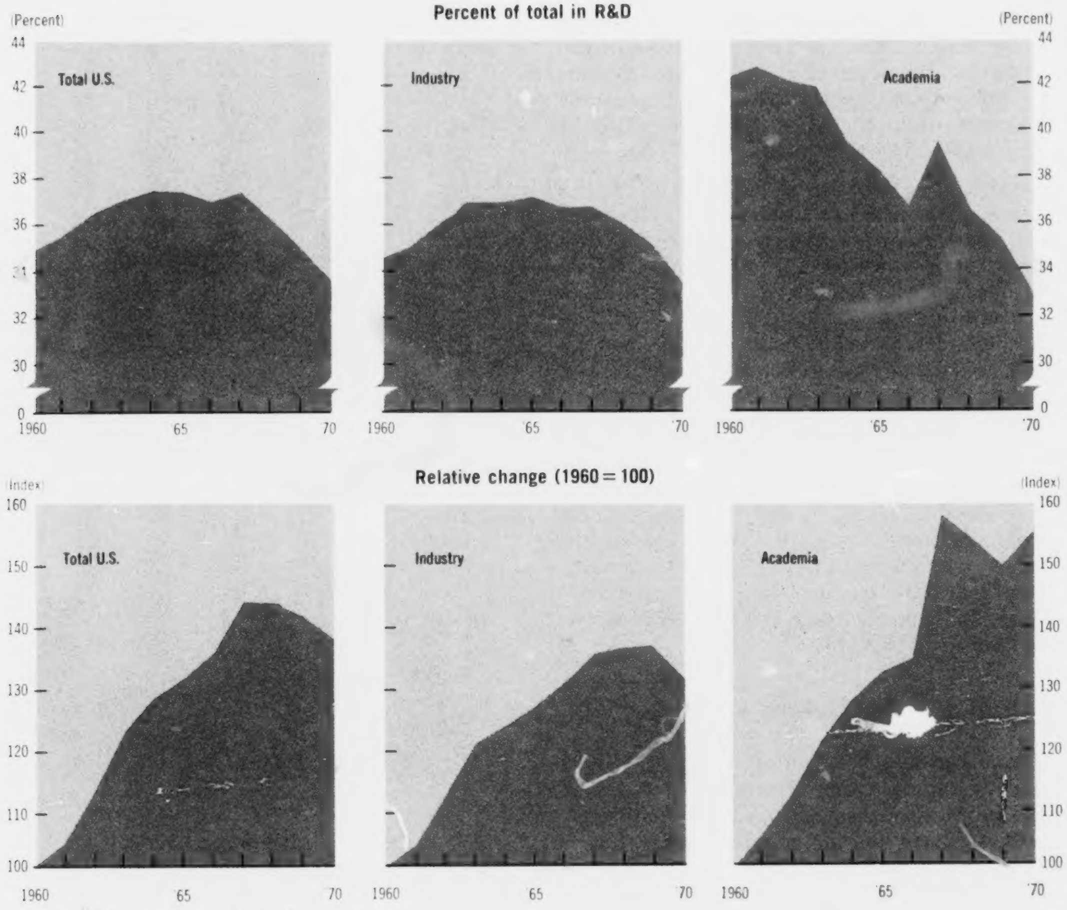
Natural Scientists and Engineers in Relation to Total Civilian Employment, 1950-70



SOURCE: Department of Labor.

Figure 37

Natural Scientists and Engineers Engaged in R&D, 1960-70



SOURCE: U.S. Department of Labor and National Science Foundation.

1970, for the first time since 1960, the total number in R&D decreased. This trend continued in 1971. Most of the decline took place in industrial R&D and was sufficient to reduce the total in this sector to the 1967 level. Not surprisingly, this downward turn followed closely the first reduction in national R&D expenditures (in constant dollars) in the 1960-70 period, a decrease felt most in industrial R&D. (See figure 14.)

Another indicator of the downward trend is the decline in the percentage of all natural scientists and engineers engaged in R&D (figure 37). This trend began as early as 1964, when it had reached a high of 37 percent. The proportion then steadily declined to 34 percent in 1970. This trend was more pronounced among academic than industrial scientists and engineers.

The relative decline of the proportion in R&D in industry suggests a greater growth of scientists and engineers in technological operations, management, and other non-R&D activities, and possibly a lower priority for R&D in periods of slow economic growth. The first factor was probably a prime cause for the decreases in the mid-1960's, while the second was dominant at the end of the decade.

The decline in the proportion of academic scientists and engineers engaged in R&D, which started as early as 1961, was primarily due to the growth in faculty needed for teaching the rapidly increasing number of college students and, secondarily, the leveling off of funds (in constant dollars) available for R&D. The first factor was dominant in the early 1960's, while both factors were important in the late 1960's.

Another noteworthy development of the 1960's was the increase (from 5 to 10 percent) of those with natural science and engineering doctorates in non-academic, non-R&D activities.[2] This change is especially significant as it took place during a "sellers' market," in which the individual scientist or engineer could usually choose his area of work. This employment trend is expected to continue, possibly at an accelerated rate, because of expected changes in the supply/demand relationship for doctorates.

The percentage of doctorates involved in R&D is considerably higher than for nondoctorate scientists and engineers, although there is substantial variation from field to field (figure 38). Especially notable are the relatively low percentages of Ph.D. mathematicians and social scientists involved in R&D.

Distribution by Employment Sector

The percentage distribution of scientists and engineers among types of employers changed somewhat during the 1960's, with a relative decline in industry and an increase in universities and colleges (figure 39). While the large size of industry as an employer tends to obscure relative increases in other sectors, figure 39 shows a significant growth in the number of scientists and engineers employed in universities and colleges and other nonprofit institutions.

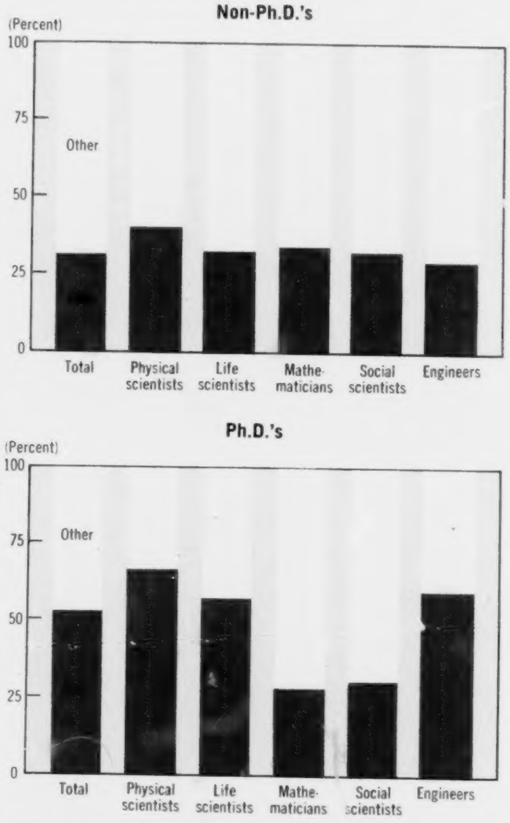
ENROLLMENTS AND DEGREE PRODUCTION

Enrollments in High School Science Courses

An early indicator of changes in student interest in science is secondary school enrollments in science courses relative to total enrollment. Figure 40 relates enrollments for 1960-61 and 1969-70 to a 1948-49 based index. Overall, enrollments in science and mathematics courses grew faster than total enrollment, with the largest growth occurring in psychology and economics and the smallest in physics, chemistry, and mathematics. The above average increase in social science course enrollments may be due in part to the limited availability of such courses in earlier years. Only in the field of physics was the growth less than increases in total enrollment.

Figure 38

Distribution of Scientists and Engineers, by Activity and Broad Field, 1970



SOURCE: U.S. Department of Labor and National Science Foundation.

College and University Enrollments and Degree Production

Enrollments. The fraction of first-year college students who intend to work toward careers as

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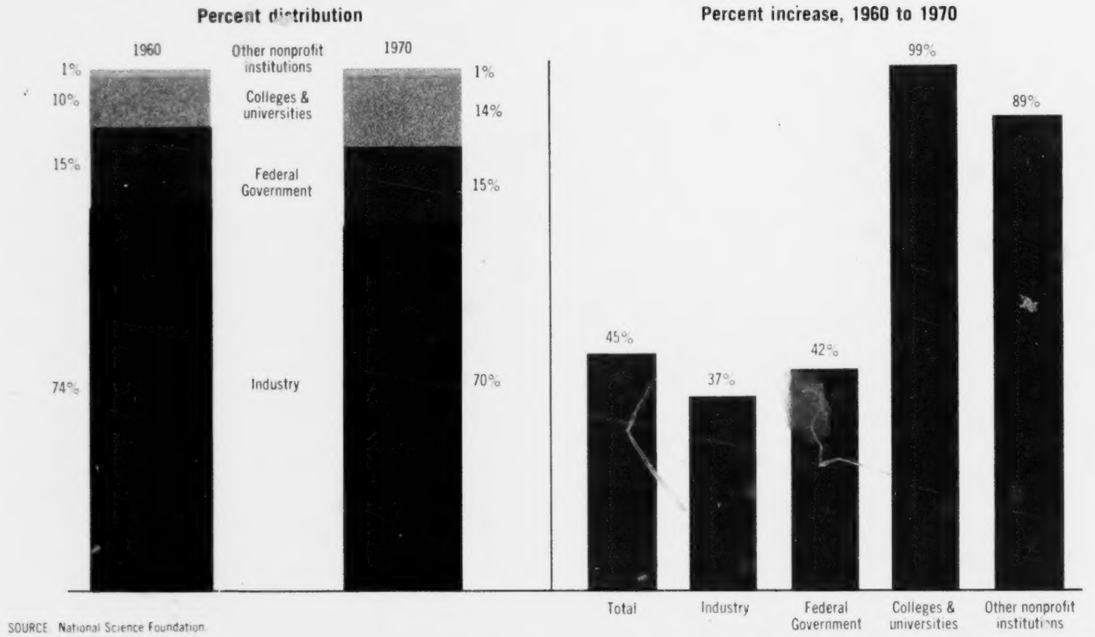
[2] National Science Foundation, *1969 and 1980 Science and Engineering Doctorate Supply and Utilization*, NSF 71-20.

Figure 39

Employment of Natural Scientists and Engineers, by Sector, 1960 and 1970



SOURCE: National Science Foundation.

research scientists decreased steadily, from 3.5 percent in 1966 to 2.5 percent in 1971. However, because of larger total enrollments, the absolute number of students intending to pursue this career remained at about the same level. Interest in engineering careers decreased from 9.0 to 5.3 percent over the same period. Although college freshmen frequently change their career interests, such changes have been generally away from science and engineering.[3]

This early indicator becomes more significant when related to fields selected by junior-year undergraduates for their major area of study. While total junior-year undergraduate enrollments increased by 7.6 percent between the fall of 1970 and the fall of 1971, fewer students chose majors in physics, chemistry, engineering, and mathematics, while basic social science, other physical science, and life science majors increased; applied social science students grew markedly (figure 41).

Similar trends are evident in terms of enrollments for advanced degrees. Annual data from the Office of Education indicate that total enrollment for advanced degrees in science and engineering fields more than doubled between 1960-70. However, such enrollment, as a percent of that in all fields, remained constant at about 38 percent until 1963, before declining steadily to 31 percent in the fall of 1970. Engineering and the physical sciences accounted for most of this decline.

Related data, though not strictly comparable with those of the Office of Education, indicate some recent trends in graduate enrollment. Data collected by the National Science Foundation from 2,579 Ph.D.-granting departments showed a decline of 7.1 percent in first-year, full-time science and engineering graduate students from fall 1969 to fall 1971, with most of this change occurring in the last year. In the same period, the number of full- and part-time graduate students in these fields declined by 3.7 percent. The overall change in first-year, full-time students includes greater-than-average declines in mathematics and the physical and social sciences,

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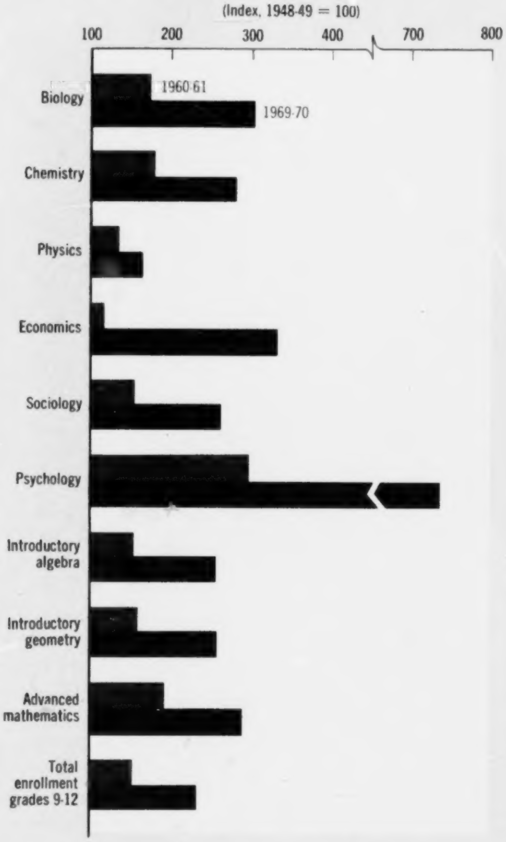
[3] American Council on Education, *Four Years After College Entry*, ACE Research Reports, Vol. 8, no. 1, March 1973.

Figure 40

Public Secondary School Enrollment in Selected Sciences and Mathematics Courses and Total Enrollment in Grades 9 through 12, 1960-61 and 1969-70



SOURCE: U.S. Office of Education and National Science Foundation.

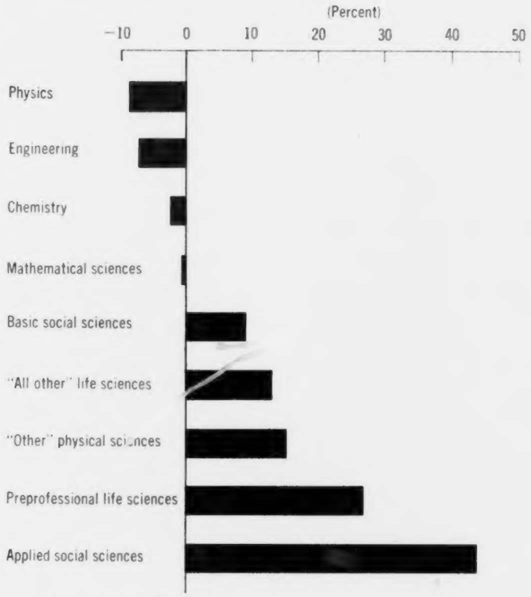
and smaller decreases in engineering, psychology, and the life sciences, as shown below.

Change in First-year, Full-time Graduate Enrollment in Science and Engineering in Doctorate Institutions, 1969 to 1971

	Percent change 1969 to 1971
All areas	— 7.1
Engineering	— 0.3
Physical sciences	—15.2
Mathematics	—12.0
Life sciences	— 5.3
Social sciences	— 9.3
Psychology	— 3.3

Figure 41

Percent Change in Majors Declared by Junior-Year Students, 1970 to 1971



SOURCE: Ace Higher Education Panel.

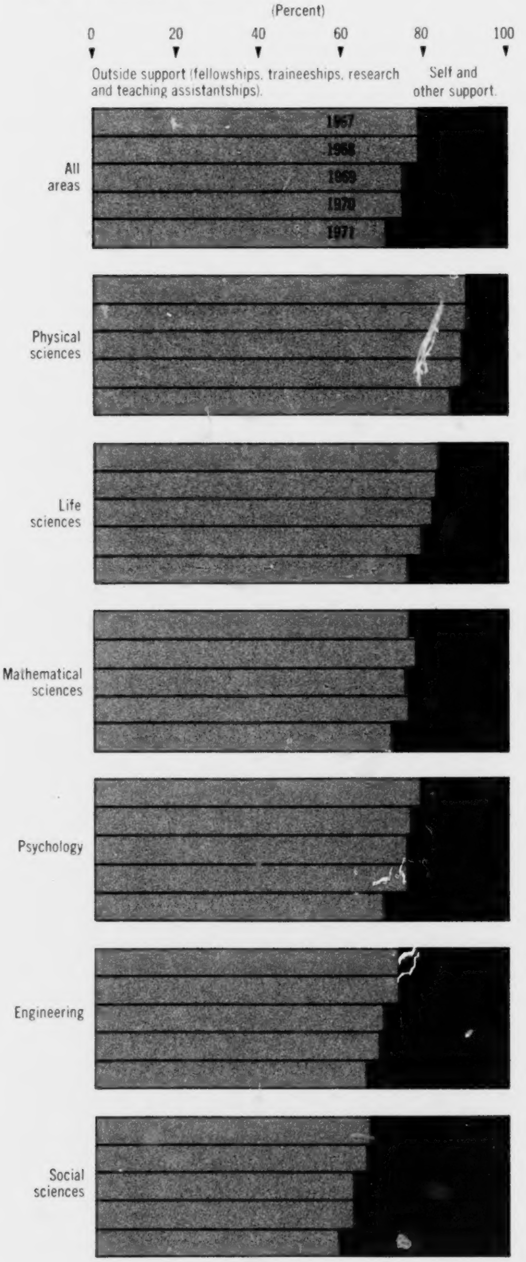
Financial Support. The availability of financial support may influence the number of graduate students entering the sciences and engineering, although the measurement of such direct effects may be confounded by university efforts to provide support for students in all fields of graduate study. Moreover, there are certainly other motivational factors affecting the choice of field for graduate education.

The sources of graduate support for major fields of science and for engineering are shown in figures 42 and 43. The largest percentage of students supported by fellowships, traineeships, and assistantships is in the physical sciences, and the smallest in the social sciences. The number of science and engineering students supported by the Federal Government declined by 15 percent between 1969-71 whereas those depending on self-support increased by 19 percent (from a lower base).

Graduate Production. Annual awards of bachelor's and first professional degrees in the sciences and engineering are shown in figure 44 for the 1959-71 period. The annual recipients of

Figure 42

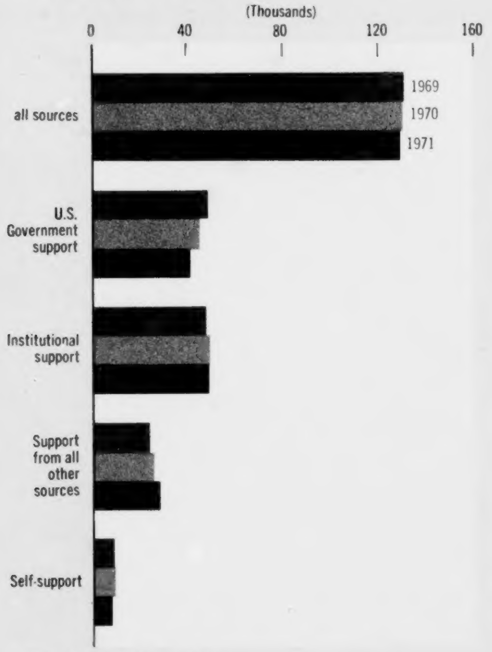
Distribution of Full-time Graduate Students in Doctorate Departments, by Area of Science and Type of Support, 1967-71



SOURCE: National Science Foundation.

Figure 43

Distribution of Full-time Graduate Students in Science and Engineering, by Source of Support, 1969-71



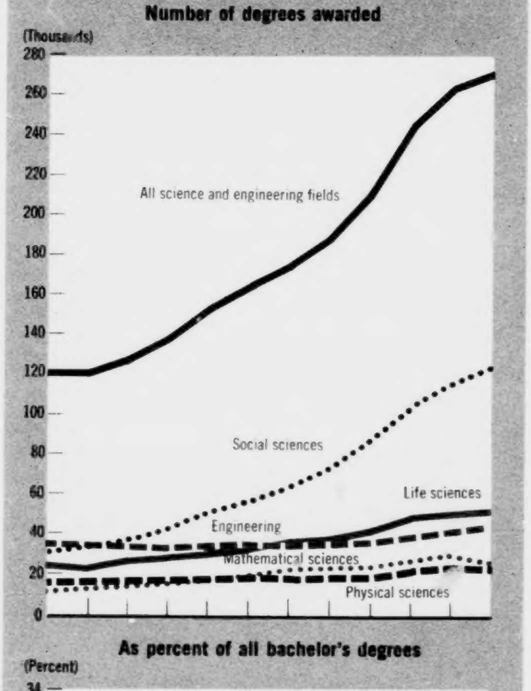
SOURCE: National Science Foundation.

social science degrees increased by a factor of 4.1 over the period, well above the growth (2.2 times) in the total science and engineering degrees awarded at that level. Social science degrees—as a proportion of all first degrees in science and engineering—rose from about one-fourth in 1959-60 to almost one-half in 1970-71. The annual production of graduates in the life and mathematical sciences increased by factors of 2.2 and 2.4, respectively, over the period, whereas those receiving degrees in the physical sciences and engineering rose by factors of only 1.3 and 1.2, respectively.

First degrees in science and engineering, as a fraction of first degrees in all fields, remained essentially constant at some 30 percent between 1959-71. The large increase in the annual recipients of social science degrees was responsible for maintaining the fraction at a constant level; engineering degrees, as a proportion of degrees in all fields, declined continuously from 9.6 percent to 5.1 percent during the period, and the physical sciences fell from 4.1 to 2.4 percent.

Figure 44

Bachelor's and First Professional Degrees in Science and Engineering, 1959-60 to 1970-71



SOURCE: U.S. Office of Education.

Annual awards of master's degrees in science and engineering are shown in figure 45. The number of these degrees awarded annually increased by a factor of 2.5 during the period, with the largest increases occurring in the mathematical (3.8) and social (3.1) sciences and the smallest in the physical sciences (1.9). As a fraction of master's degrees in all fields, sciences and engineering degrees declined from a high of 30 percent in 1964-65 to 22 percent in 1970-71. The largest proportional declines were in engineering and the physical and life sciences. This may indicate that relatively fewer persons were seeking advanced degrees in these fields, or that there is a trend toward working directly for the Ph.D.

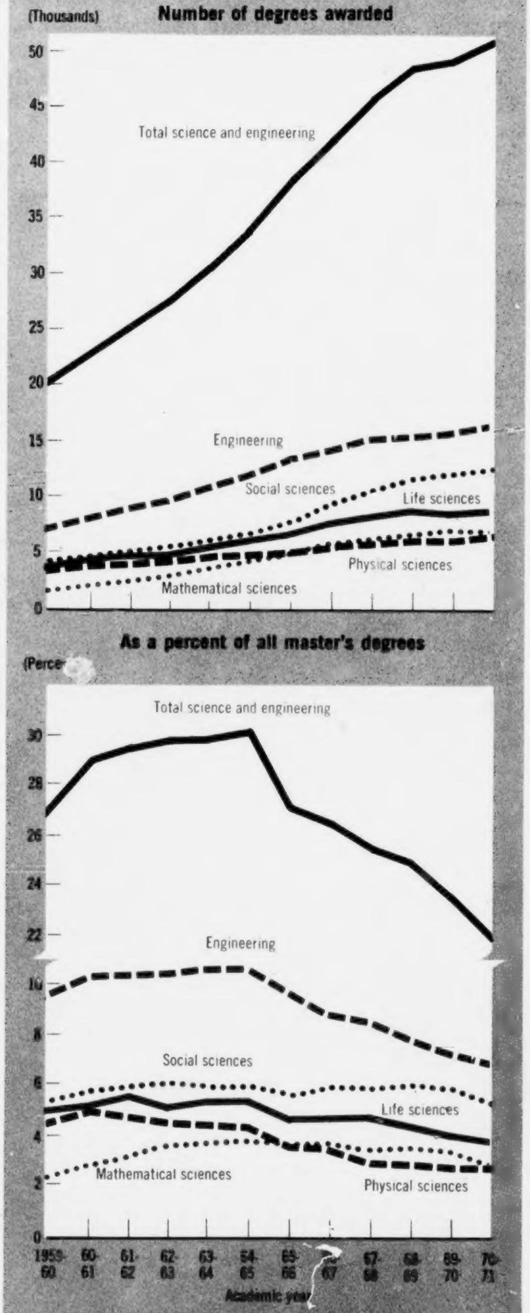
Annual awards of Ph.D. degrees are presented in figure 46. The greatest growth occurred in engineering, which inreased by a factor of 4.6, and in the mathematical sciences (4.4), both of which exceeded the 3.0 increase for total Ph.D. degrees in science and engineering. The life and social sciences increased by factors of 2.9, and the physical sciences by 2.4. As a percentage of Ph.D. degrees in all fields, the annual recipients of doctorate degrees in the sciences and engineering declined from a high of 62 percent in the mid-1960's to 58 percent in 1970-71. The largest proportional declines were in the physical sciences.

The rapid growth of recipients of science and engineering degrees is not a development specific to science. Even in the case of the Ph.D. degree, where the growth rate was greatest, the ratio of science to nonscience Ph.D.'s has remained almost constant since the early 1920's. Furthermore, the rapid growth rate is not solely a matter of advanced education. A large part of our modern 20th-century society exhibits the same rapid growth; this appears in such areas as the annual production of books, telephones in use, production of electronic systems, consumption of electricity, and use of raw materials.

While growth rates in science and engineering degrees granted during the 1960's were substantial, they at most kept pace with degrees granted in other fields. Actually, first degrees in natural science and engineering—and nearly all advanced science and engineering degrees—grew more slowly than degrees in all other fields combined. The relative decline has been most pronounced for first and master's degrees in engineering and for doctorates in the physical sciences. Taken as a whole, these indicators point to a relative decline in students

Figure 45

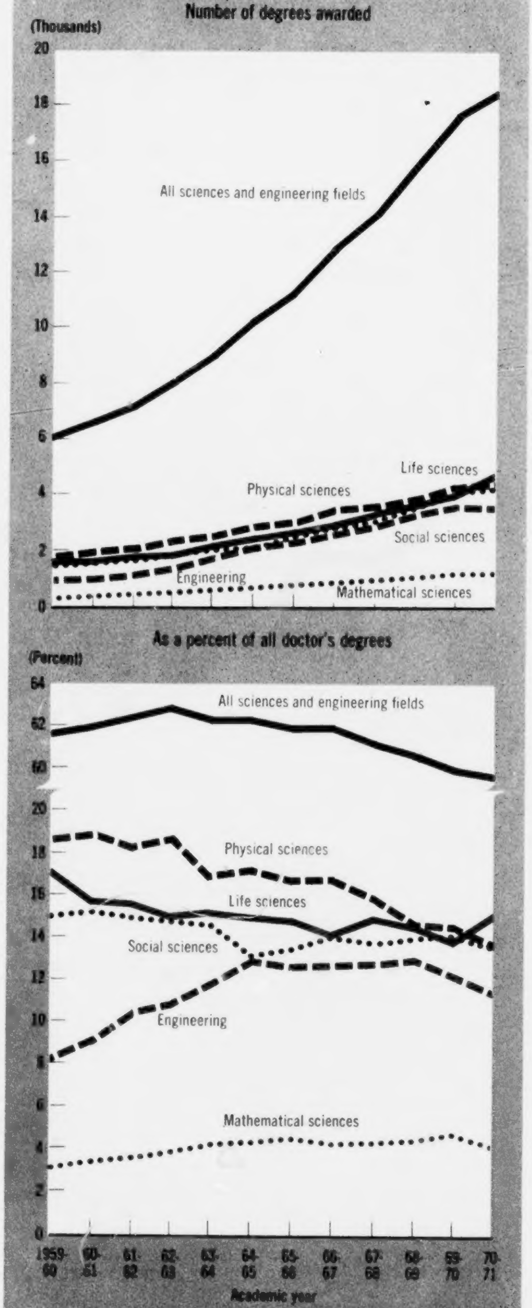
Master's Degrees in Science and Engineering, 1959-60 to 1970-71



SOURCE: U.S. Office of Education.

Figure 46

Doctor's Degrees in Science and Engineering, 1959-60 to 1970-71



SOURCE: U.S. Office of Education.

majoring in science and engineering fields, although the absolute numbers of those who so choose are still increasing.

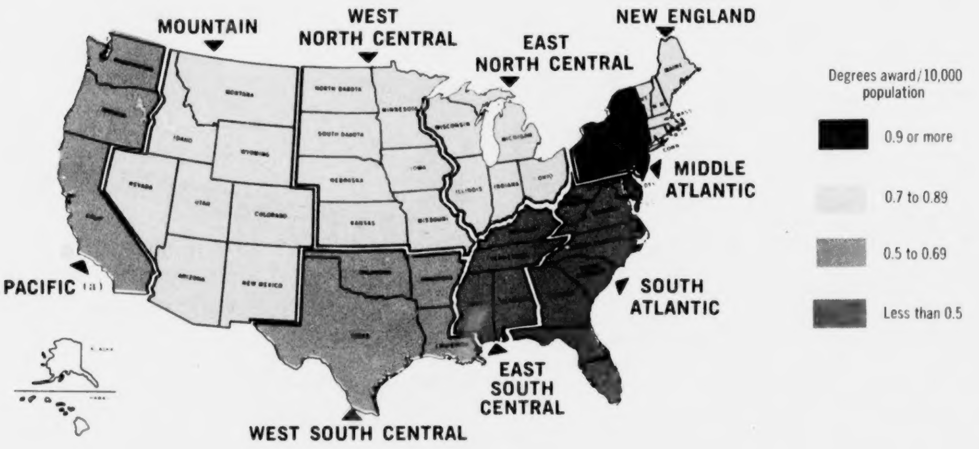
Doctorate Awards by Geographic Region

Figure 47 shows science and engineering Ph.D.'s awarded in terms of the geographic region of high school graduation in relation to the population of those regions. This ratio varies considerably with New England, the Middle Atlantic, West North Central, and Mountain regions showing larger proportions, while the South Atlantic and East South Central regions are lower by almost 50 percent. This indicator shows an uneven pattern of pursuit of advanced education (to the doctorate) among high school graduates, although some progress was made in reducing these regional differences during the last decade.

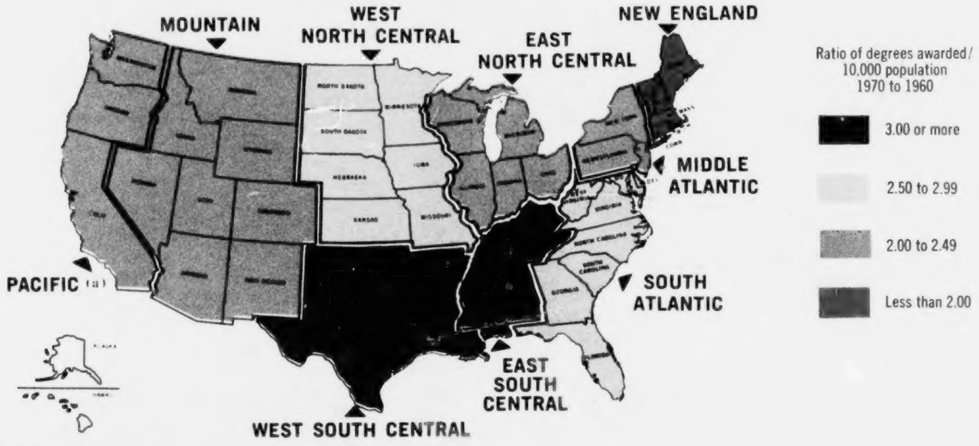
Figure 47

Geographic Origins, by High School Graduation, of Ph.D.'s in Science and Technology, 1970

1970


MOUNTAIN
WEST NORTH CENTRAL
EAST NORTH CENTRAL
NEW ENGLAND
MIDDLE ATLANTIC
SOUTH ATLANTIC
EAST SOUTH CENTRAL
WEST SOUTH CENTRAL
PACIFIC (a)
Degrees award/10,000 population
0.9 or more
0.7 to 0.89
0.5 to 0.69
Less than 0.5

1970 compared with 1960


MOUNTAIN
WEST NORTH CENTRAL
EAST NORTH CENTRAL
NEW ENGLAND
MIDDLE ATLANTIC
SOUTH ATLANTIC
EAST SOUTH CENTRAL
WEST SOUTH CENTRAL
PACIFIC (a)
Ratio of degrees awarded/10,000 population 1970 to 1960
3.00 or more
2.50 to 2.99
2.00 to 2.49
Less than 2.00

(a) Includes Alaska and Hawaii.

SOURCE: National Research Council and National Science Foundation.

SUPPLY AND UTILIZATION

Unemployment

For most of the 1960's the production of new scientists and engineers could not match the demand for their services. In recent years, however, the demand for scientists and engineers declined as a result of several converging factors: R&D funding (in constant dollars) declined on the average by 1 percent per year between 1967 and 1972, due primarily to an average annual decline of 3.3 percent in Federal R&D funding; concurrently, the Nation underwent a fairly steady period of inflation, reduced economic growth, and less emphasis on space and defense.

However, because of the long timelags in the response of the educational system, the production of scientists and engineers continued in spite of the fall in demand, creating a supply/demand mismatch. Unemployment of scientists and engineers accelerated from 1969, reaching about 2.6 percent for scientists and 2.9 percent for engineers by early 1971 (figure 48). National Science Foundation surveys show that unemployment in 1971 was more severe for engineers than for scientists, as indicated in figure 49; that, generally, those with higher degrees were less likely to be unemployed; and that younger scientists and engineers were most adversely affected. Unemployment rates were more severe in the defense and aerospace areas and in specific disciplines such as physics. Among unemployed scientists and engineers, defense (11 percent) and space-related activities (4 percent) were most frequently cited as the last areas of employment.

Although there was a relative increase in the unemployment of scientists and engineers, the base level for such a comparison was low. Even with the large relative increases up to 1971 the overall science and engineering unemployment rate was still only about half that for all workers.

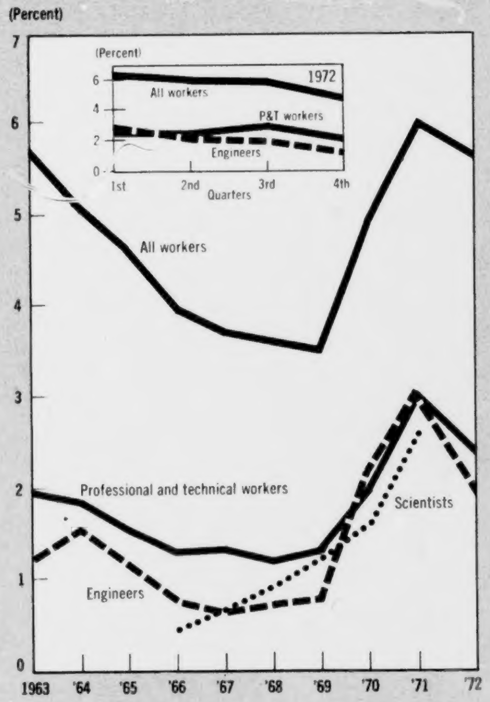
The unemployment situation has improved somewhat since then. The unemployment rate for scientists and engineers declined in 1972, as has that for all professional workers, and employment prospects for new graduates were reported as better in 1972, although still not as good as those in the mid-1960's.

Underemployment

Although unemployment has been relatively small, the change from a "sellers' market" to a "buyers' market" has tended to produce underemployment—employment that fails to fully utilize the training of scientists and engineers. Although a real problem, underemployment is difficult to assess since "underutilization of training" is a subjective judgment. Some indication of underemployment of new Ph.D.'s can be inferred from a survey of university department chairmen conducted by the National Research Council.[4] The survey found that in January 1971, 1.2 percent of new (1968-69) Ph.D.'s were listed as employed in positions that did not make appropriate use of their graduate training, and that this percentage was double that reported the year before.

Figure 48

Unemployment Rates, 1963-72



SOURCE: U.S. Department of Labor.

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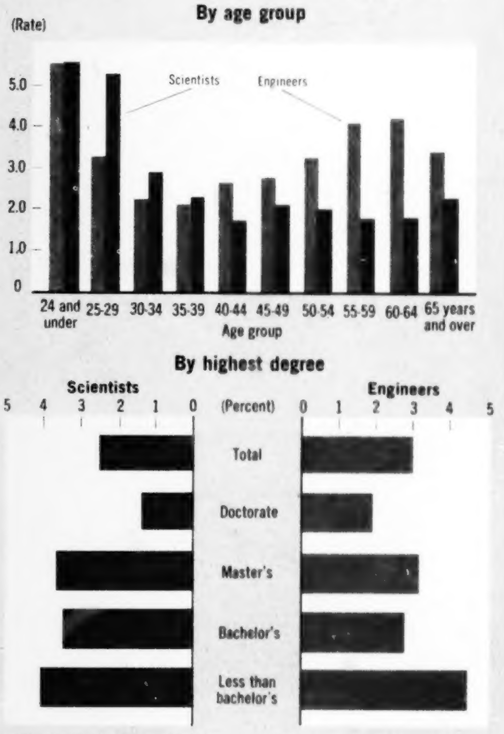
[4] National Research Council, *Employment of New Ph.D.'s and Postdoctorals in 1971*, Washington, D.C., 1971.

Figure 49

Unemployment Rates for Scientists and Engineers, by Age Group and Highest Degree, 1971



SOURCE: National Science Foundation

Holding Actions

Several other factors should be considered in a review of employment. For most of the 1960's, the percentage of those who planned to continue their training immediately upon receipt of their science and engineering Ph.D.'s remained essentially constant, except for those in the life and physical sciences, who showed a steadily increasing tendency toward postdoctoral study (figure 50). Then, in the late years of the decade, the fraction of all Ph.D.'s taking postdoctoral study increased somewhat.[5] This may, in part, have been an early indicator of the shrinking employment market for scientists and engineers. The number of science and engineering Ph.D.'s in temporary postdoctoral study was still increasing in 1971. The availability of postdoctoral study thus provides a number of new Ph.D.'s with an alternative to employment competition and at least temporarily helps relieve pressure on the labor market.

A related matter is the length of time between receipt of the bachelor's degree and the doctorate. The median time had been decreasing in almost all fields when, in 1968-69, it started to rise again in the physical sciences, mathematics, engineering, and the life sciences (figure 51). This may be due in part to graduate students attempting to prolong their study because of the scarcity of jobs.

Age Distribution

Without a flow of young people into science and engineering, creativity in these fields would tend to decline overall, as would be the case in any profession. In the last decade or so, the number of scientists or engineers, particularly the doctorate population, has grown substantially. Therefore, with this large flow of new entrants the average age has not risen; for doctorates it has actually declined.

Based on current and projected degree production and projected growth in employment, it appears that the average age of the science and engineering population will not rise substantially in the coming decade. However, even though the overall average age may not change markedly, the proportion in the younger age groups will decrease significantly unless recruitment of new young talent continues.

Other Changes

As mentioned previously, the deployment of doctorates into nonacademic, non-R&D activities increased during the 1960's. This trend increased during the most recent years, as supply expanded relative to demand. Similarly, increased employment of doctorates was evident in junior and community colleges, as well as in 4-year institutions. The number of doctorates employed full time in the former institutions increased nearly twice as fast as all science and engineering staff between 1969 and 1971, with the result that the proportion of full-time staff holding doctorates increased from 8.8 to 10.6 percent in 2-year institutions.[6]

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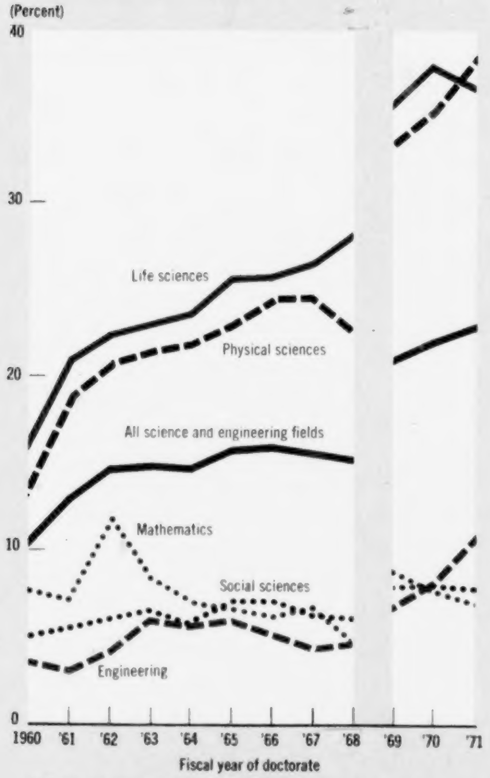
[5] The sharp increases shown in figure 50 between 1968 and 1969 are misleading because of changes in definitions in postdoctorate study. However, analysis of the data indicates increases in the proportion over earlier years.

[6] National Science Foundation, *Resources for Scientific Activities at Universities and Colleges, 1971*, NSF 72-315.

Figure 50

Percent of New Science and Engineering Ph.D.'s Planning to Engage in "further education or training" or "postdoctoral study," by Field, FY 1960-71 (a)

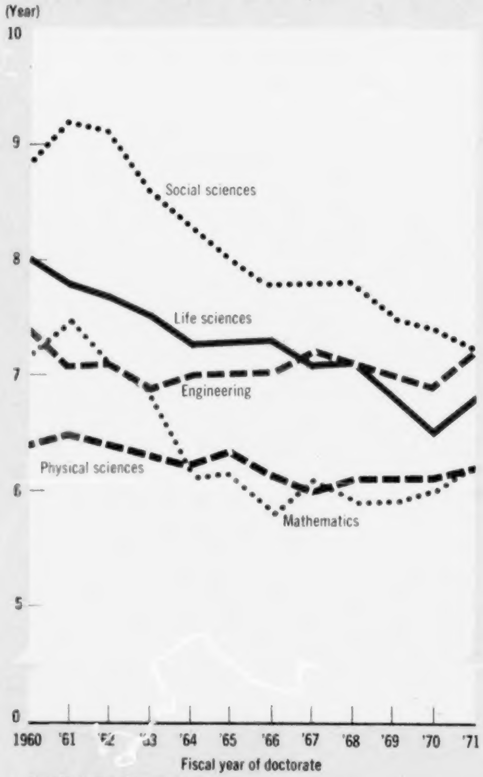


(a) Due to a change in definition, 1969 through 1971 data are not strictly comparable with earlier years.

SOURCE: National Research Council.

Figure 51

Median Number of Years from Baccalaureate to Doctorate of Doctorate Recipients in Science and Engineering, by Field, FY 1960-71



SOURCE: National Research Council.

Institutional Capabilities

Institutional Capabilities

This chapter presents indicators of the state of the institutional system of science and technology. The indices include aspects of the infrastructure involved in training scientists and engineers; types and numbers of organizations engaged in R&D; composition and patterns of concentrations among these organizations; and expenditures for research equipment and facilities. Indicators of these several aspects are presented in the context of the system of institutions—colleges and universities, Federal installations, and industry—within which the bulk of training and R&D is accomplished.

The present indicators in this area are incomplete in several respects, primarily because of the lack of current and/or detailed information. No indicators are presented for nonprofit institutions or for local government; only fragmentary and dated information was available on the number, size, and activities of Federal installations; indicators of industrial R&D are limited to relatively aggregated aspects of expenditure and manpower; and indices of the state of research equipment and facilities do not include information on the quantity, type, and utilization of scientific instruments and specialized facilities.

INDICATOR HIGHLIGHTS

- The number of academic institutions awarding degrees in science and engineering increased from some 1,100 in 1960-61 to almost 1,300 in 1969-70, with the largest increases occurring in institutions which awarded master's and Ph.D. degrees.
- Doctoral-granting institutions employed almost 75 percent of all academic scientists and engineers in recent years, and awarded more than 80 percent of all master's degrees in science and engineering and more than 50 percent of the bachelor's degrees.
- The 20 institutions awarding the most Ph.D. degrees in science and engineering accounted for a decreasing fraction of all such degrees awarded, down from one-half of the total awards in 1963 to two-fifths in 1971. Science and engineering graduate enrollments in these institutions declined proportionally over the period.
- Private doctoral institutions awarded a decreasing proportion of all Ph.D. degrees in science and engineering, falling from 41 percent of the total awards in 1963 to 34 percent in 1971. Science and engineering graduate enrollments in these institutions peaked in 1969 and declined thereafter, in contrast to the continued growth of such enrollments in public institutions.
- New doctoral programs in existing doctoral departments increased at the net rate of 1 program per 26 departments during 1970-72; plans for 1972-74 indicate a reduction of the ratio of new additions to 1:66. The largest net increases were in the areas of computer sciences and psychology.
- Expenditures for laboratory equipment, provided through research grants from the National Science Foundation and major National Institutes of Health, declined between 1966-71. These expenditures as a fraction of total grant funds, fell from 12 percent to 6 percent during the period.
- Federal obligations to universities and colleges for R&D plant and major equipment declined 75 percent between 1965 and 1971. As a proportion of all Federal obligations for academic science, funds for R&D plant dropped from 8 percent to 1 percent during the period.
- A radio astronomy facility (known as the VLA) authorized and funded in FY 1973 was the first new major research facility started since 1968, although some 30 facilities, in various areas of science, were proposed in recent years and evaluated as technically desirable and feasible.
- Federal intramural R&D expenditures increased throughout the 1961-72 period, with the Department of Defense accounting for the largest share of such funds, followed by NASA, the Department of Agriculture, and

the Department of Health, Education, and Welfare. Together, these four agencies accounted for 86 percent of total such expenditures in 1972.

- Federal intramural R&D expenditures, as a percent of total U.S. R&D expenditures, increased from 13 percent to 16 percent between 1960-72, while the number of scientists and engineers (full-time-equivalent) engaged in such R&D rose from 12 to 13 percent of the U.S. total between 1961-71.
- Large industrial companies (5,000 or more employees) employed an increasing proportion of the total industrial R&D personnel between 1963 and 1971 (up from 79 percent to 85 percent), while the share for small companies (less than 1,000 employees) declined from 10 percent to 6 percent.
- The R&D intensiveness of U.S. industry, as measured by the ratios of R&D expenditures to net sales and R&D scientists and engineers to total employment, increased between 1960-64 but declined thereafter to a level in 1970 which was lower than in 1960. The largest declines occurred in the most R&D intensive industries.
- The R&D intensiveness of manufacturing industries declined by some 25 percent between 1964-70 in the five most R&D-intensive industries, and remained essentially unchanged in other manufacturing industries during the 1960-70 period.
- The R&D intensiveness of nonmanufacturing industries increased by 50 percent between 1960 and 1966, but remained constant thereafter through 1970.
- Industrial R&D is concentrated in relatively few manufacturing industries and in a small number of companies within these industries. In 1970, five industries had 81 percent of the total industrial R&D expenditures, while accounting for only 48 percent of total manufacturing sales, and 100 companies had some 80 percent of the total expenditures.

■ Scientific and technological activities are performed through a mutually complementary system of institutions and associated human resources. The system of institutions consists principally of colleges and universities, which both train scientists and engineers and perform research; Federal laboratories, which focus primarily on research and development directly related to their respective missions; and private industry, which conducts research and development leading to new and improved technology, processes, and products. The characteristics and capabilities of this system can be described in terms of the types of institutions involved, the activities they perform, and the effectiveness with which the education and/or R&D functions are carried out.

SCIENCE AND ENGINEERING EDUCATION

General Institutional Capabilities

Higher education in the sciences and engineering grew rapidly throughout the past decade. The number of colleges and universities awarding science and engineering degrees in each year between 1961-71 is shown in figure 52. The major growth was in institutions which granted the master's and Ph.D. degrees; their numbers increased by 57 and 45 percent, respectively. Institutions at the bachelor's degree level failed to show the same systematic growth, in part because of the widespread evolution of these colleges into higher level institutions.

Scientists and engineers employed by universities and colleges are concentrated in doctoral-granting institutions. In 1971 these institutions employed almost 75 percent of all academic scientists and engineers, a fraction which remained essentially unchanged during recent years[1] (figure 53). The institutions awarded more than 80 percent of all master's degrees in science and engineering and more than 50 percent of the bachelor's degrees during the 1964-70 period (figure 54).

Patterns of Growth in Doctorate Institutions

Institutional capabilities for graduate education in science and engineering grew in

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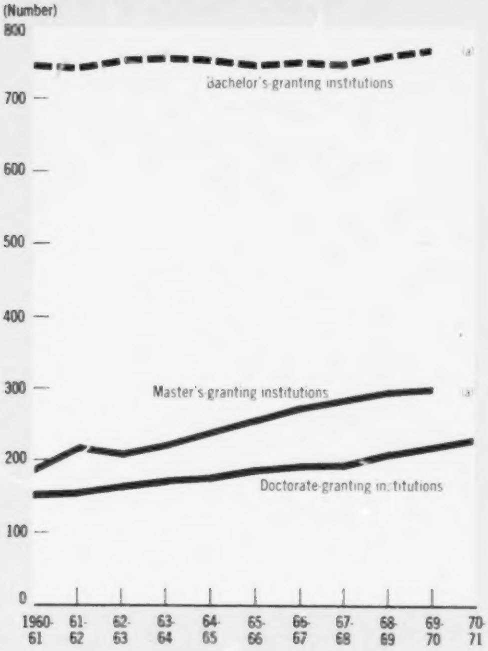
[1] Two-year institutions and other institutions which do not grant science or engineering degrees are not included.

Figure 52

Number of Institutions of Higher Education by Highest Degree Awarded in Science and Engineering, 1960-61 to 1970-71



(a) Not available.

SOURCE: U.S. Office of Education and National Science Foundation.

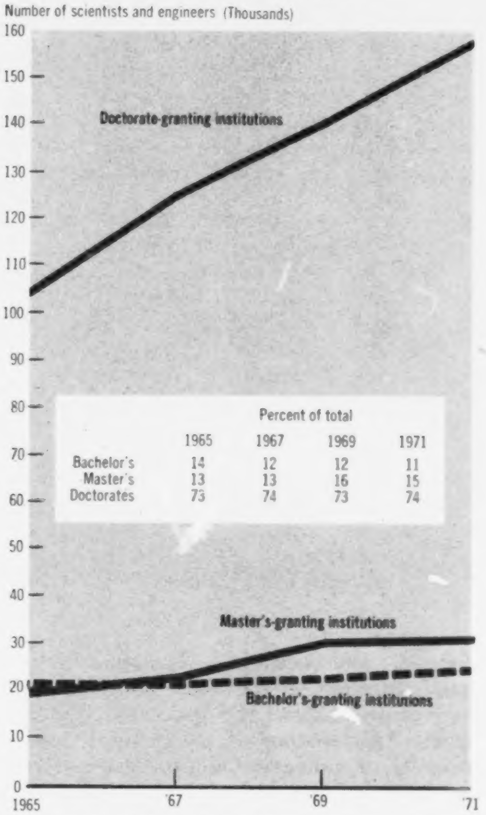
two ways: the number of graduate-level institutions increased and existing graduate institutions expanded their graduate programs. Some aspects of the growth pattern of doctoral institutions are shown in the following tables.

The first table shows the growth in the number of Ph.D.-level institutions and the division of doctorate awards among them. The increasing number of institutions are divided into three groups, in terms of the number of Ph.D. degrees awarded.

Institutions granting	*Number of institutions granting Ph.D.'s*			
	1962-63	*1965-66*	*1969-70*	*1970-71*
First one-third of Ph.D.'s	11	13	15	16
Next one-third of Ph.D.'s	24	28	35	36
Last one-third of Ph.D.'s	127	146	172	177
Total number of institutions	162	187	222	229

Figure 53

Scientists and Engineers[a] Employed by Universities and Colleges, 1965-71



	Percent of total			
	1965	1967	1969	1971
Bachelor's	14	12	12	11
Master's	13	13	16	15
Doctorates	73	74	73	74

(a) Includes all scientists and engineers (full-time-equivalent basis) employed in universities.

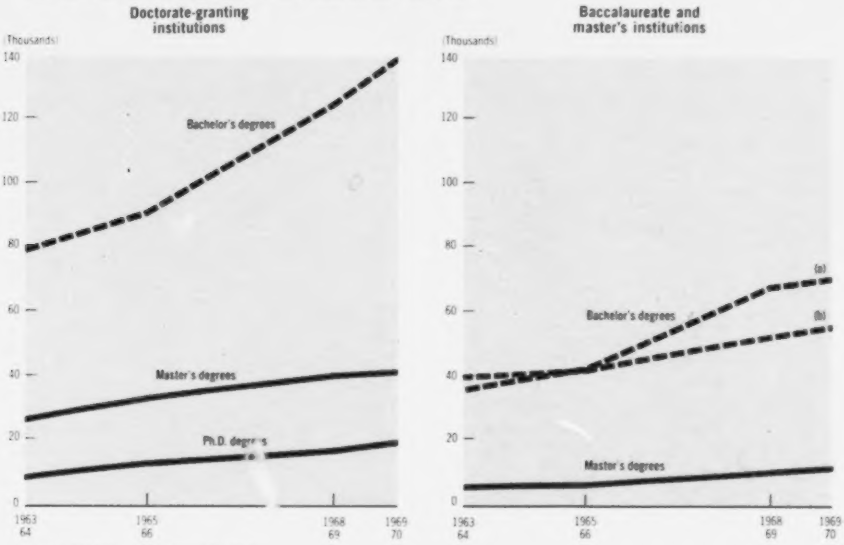
SOURCE: National Science Foundation.

The table shows that the number of institutions in each group increased, with the largest increase occurring in institutions which awarded the smallest number of Ph.D.'s. Growth in the last group of institutions, however, was matched by the expansion of graduate programs in the larger Ph.D.-granting institutions. Thus, in 1970-71 as in 1962-63, 7 percent of the institutions produced one-third of all science and engineering Ph.D.'s, 15 percent produced the second third, and 78 percent produced the remaining one-third of the Ph.D.'s.

The proportion of full-time graduate students enrolled in the three groups of institutions over the 1962-71 period are shown in the following table.

Figure 54

Science and Engineering Degrees Awarded at Baccalaureate, Masters, and Doctorate-Granting Institutions, 1963-64 and 1969-70



(a) Master's institutions (b) Baccalaureate institutions

SOURCE: Office of Education and National Science Foundation

Institutions granting	*Percent of total full-time enrollment for advanced degrees*			
	1962-63	*1965-66*	*1969-70*	*1970-71*
First one-third of Ph.D.'s	29	29	28	28
Next one-third of Ph.D.'s	29	30	31	31
Last one-third of Ph.D.'s	42	41	41	41

This table shows the close correspondence between the proportion of graduate students in the three groups of institutions and the proportion of Ph.D.'s produced by them.[2] Similarly, there was little change over the period in the proportional distribution of students among the three groups of institutions. First-year, full-time graduate students shows a similar division and constancy among the groups of institutions.

Institutions granting	*Percent of first-year full-time enrollment for advanced degrees*			
	1962-63	*1965-66*	*1969-70*	*1970-71*
First one-third of Ph.D.'s	25	25	25	26
Next one-third of Ph.D.'s	27	29	29	28
Last one-third of Ph.D.'s	49	46	46	46

Other patterns of growth are indicated by using a different method of grouping institutions; namely, the first 20 institutions ranked in terms of numbers of Ph.D.'s awarded, the next 20 institutions, and all other doctorate-granting institutions.

The individual institutions included in the first two groups changed in rank considerably between 1962-63 and 1970-71 as shown in the table on page 68. Institutions in these groups generally have the following characteristics: they were usually among the top institutions in terms of Federal funds received, were the choice of the largest numbers of Federal fellowship awardees, and were generally included among the highly ranked graduate departments as categorized by the American Council on Education.[3]

The increase in Ph.D. degree awards and graduate enrollments among these groups of institutions are shown in figures 55 and 56. Although the number of science and engineering

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[2] The deviation may be due to a greater tendency for students in the last group of institutions to conclude their education with the master's degree, to transfer to larger institutions for the Ph.D., or to discontinue graduate education.

[3] K. D. Roose and C. J. Andersen, *A Rating of Graduate Programs*, American Council on Education, 1970.

Changes in Ranking of 40 Institutions Conferring the Largest Number of Ph.D.'s in the Sciences and Engineering, in terms of Number of Ph.D.'s Conferred and Amount of Federal Obligations Received

Rank in order of Ph.D. degrees conferred			*Rank in order of total federal obligations*[1]	
1970-71	*1962-63*		*1970-71*	*1962-63*
1	1	University of Illinois	6	8
2	2	University of California-Berkeley	10	4
3	3	University of Wisconsin	3	11
4	7	University of Michigan	4	2
5	11	Stanford University	7	7
5	15	Cornell University	17	12
7	5	Purdue University	40	27
8	4	Massachusetts Institute of Technology	1	1
9	8	University of Minnesota	2	9
10	20	Michigan State University	30	29
11	14	University of California-Los Angeles	9	10
12	10	Ohio State University	15	19
13	6	Harvard University	8	5
14	22	University of Washington	5	15
15	9	Columbia University	11	3
16	18	Pennsylvania State University	39	31
17	13	Iowa State University	56	45
18	17	University of Texas	38	20
19	23	Northwestern University	44	22
20	12	University of Chicago	20	6
20	16	New York University	18	13
22	25	University of Pennsylvania	16	17
23	49	University of Missouri	22	41
23	[2]	Case-Western Reserve University	42	[2]
25	27	University of Maryland	28	33
26	43	University of Tennessee	35	38
27	54	Texas A & M University	46	44
28	40	University of Florida	41	37
28	24	Indiana University	31	34
30	64	University of Arizona	53	62
31	21	Yale University	19	16
32	19	Princeton University	63	24
32	44	North Carolina State University-Raleigh	51	54
34	39	University of California-Davis	52	64
35	34	University of Colorado	23	26
36	77	University of Massachusetts	78	[3]
37	42	Oregon State University	69	57
38	45	University of Southern California	24	35
38	38	University of Kansas	57	53
40	33	Duke University	26	32
40	28	University of Iowa	37	39
42	30	Louisiana State University	21	55
43	37	University of North Carolina-Chapel Hill	25	40
44	29	Rutgers-The State University	48	51
47	32	University of Pittsburgh	33	18
49	36	University of Utah	32	42
54	31	Johns Hopkins University	14	14
54	26	California Institute of Technology	45	43
57	35[4]	Carnegie-Mellon University	90	77[4]

[1] Includes funds for medical schools, but not FFRDC's.

[2] Separate institutions in 1962-63.

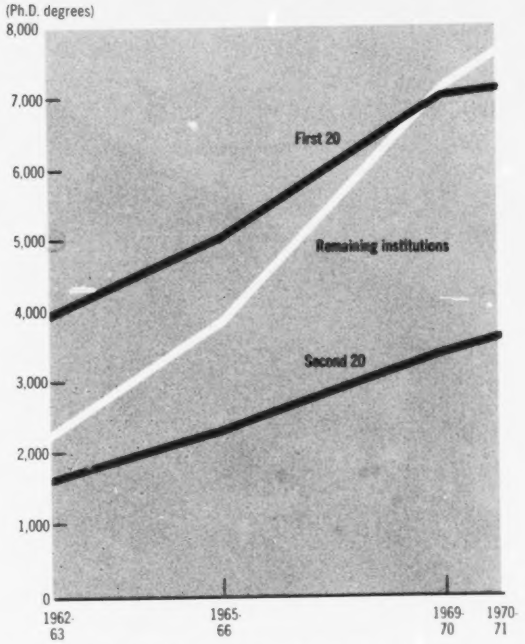
[3] Ranked below 100.

[4] Carnegie Institute of Technology in 1962-63.

Source: National Science Foundation.

Figure 55

Number of Ph.D. Degrees Awarded in Science and Engineering by Selected Groups of Doctorate-Granting Institutions [a]



[a] Ranked by number of Ph.D. degrees awarded in each year.

SOURCE: Office of Education and National Science Foundation.

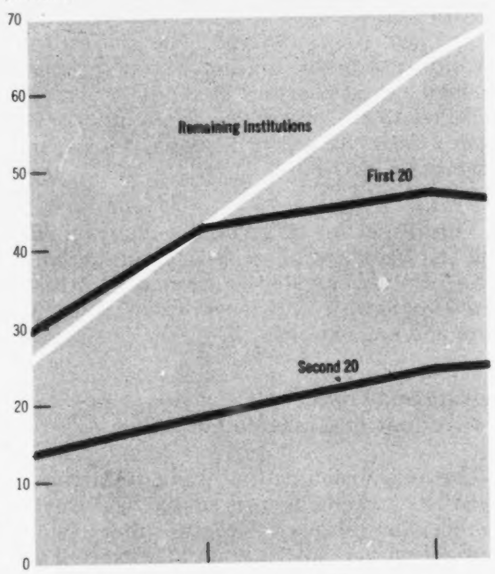
doctorates increased in each group of institutions, the smallest growth occurred in the first and second 20 institutions. As a result of this pattern, the proportion of all such doctorates awarded by the first 20 institutions declined from 51 to 39 percent between 1962-63 and 1970-71, as compared with a nearly constant proportion of 20 percent for the next 20 institutions and an increase from 29 to 42 percent for the remaining institutions.

Growth and distribution patterns similar to these occurred for graduate student enrollments, as shown in figure 56. Total full-time enrollments increased overall, although a small decline was recorded among the first 20 institutions in 1970-71. By the end of the period, the share of total enrollments for the first group of institutions had declined to 33 percent, down from 43 percent in 1962-63. The share for the

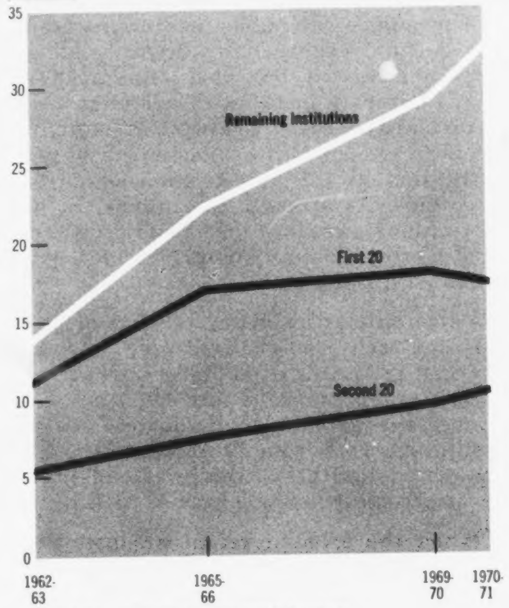
Figure 56

Graduate Students in Science and Engineering Enrolled in Selected Groups of Doctorate-Granting Institutions [a]

Total full-time students



First year, full-time students



[a] Ranked by number of Ph.D. degrees awarded in each year.

SOURCE: National Science Foundation.

next 20 institutions fell from 20 to 18 percent, whereas the proportion in other institutions rose from 37 to 49 percent.

Shifts in the same direction occurred for first-year, full-time graduate enrollment. By 1970-71, the proportion of such students in the first 20 institutions declined to 29 percent, from a high of 37 percent in 1962-63. The share of such enrollments in the second 20 institutions remained almost constant at about 17 percent, in contrast to the proportion in all other institutions which climbed to 54 percent, up from 45 percent in 1962-63.

This dispersion of graduate education during the last decade is of course a continuation of a long-run trend created by the increase in institutions involved in this level of education in science and engineering.

Private and Public Institutions in Graduate Education

The responsibility for graduate training of scientists and engineers is shared by private and public institutions. Despite their smaller number, private institutions have exerted much influence in shaping and enhancing graduate education as a whole.

The number of public institutions granting the doctoral degree in the sciences and engineering increased somewhat more rapidly than that of private institutions over the 1963-71 period, as indicated in figure 57. In each of these years an average of five public and three private institutions awarded the doctoral degree for the first time. As a result, the number of public institutions awarding the doctoral degree exceeded private institutions by 41 in 1971, as compared with 24 in 1963.

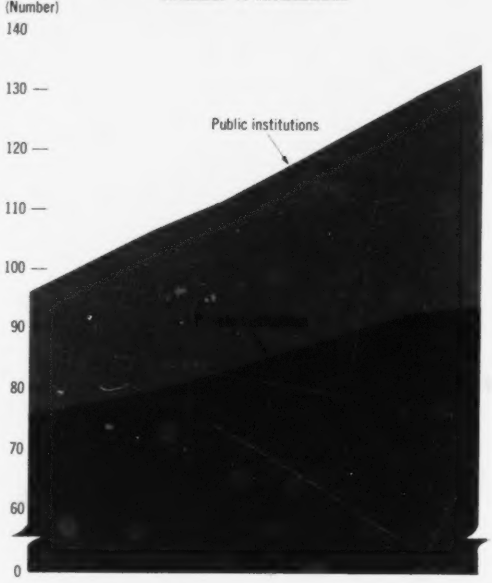
While differences in the number of institutions of each type changed only moderately, doctoral graduates from public institutions increased more rapidly (figure 57). As a consequence, the proportion of graduates from public institutions rose from 59 to 66 percent during the period and those from private institutions declined correspondingly from 41 to 34 percent.

When the level of recent graduate enrollments are considered, the diminishing role of private institutions is even more apparent (figure 58). Enrollments in private institutions peaked in 1969 and declined by 5 percent in 1970, while graduate enrollments in public institu-

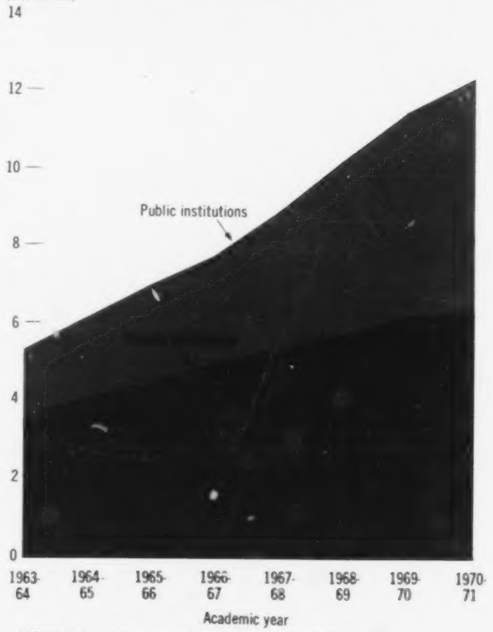
Figure 57

Institutions Granting Ph.D. Degrees in Science and Engineering, by Control, 1963-64 to 1970-71

Number of institutions



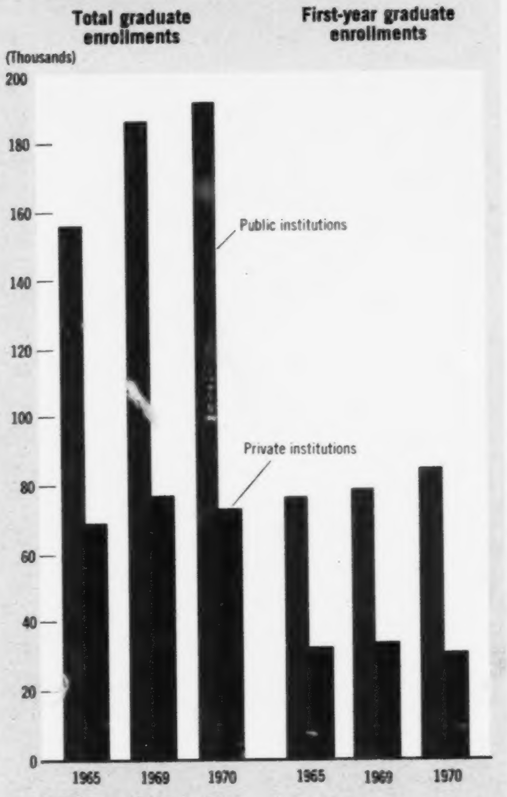
Ph.D. degrees awarded



SOURCE: Office of Education and National Science Foundation.

Figure 58

Graduate Enrollment by Control of Institutions, Selected Years, 1965-70



SOURCE: National Science Foundation.

tions continued to increase. By 1970, only 28 percent of the total science and engineering graduate students were in private institutions. Most of the decline (some 75 percent) was due to cutbacks in first-year enrollments; these fell by 9 percent between 1969 and 1970, in contrast to such enrollments in public institutions which increased 8 percent.

The largest private institutions, in terms of the number of Ph.D.'s produced, had the largest declines in first-year enrollments. Of the 20 largest Ph.D.-producing institutions, public and private, 6 are private universities. Of the six, only one had an increase in first-year enrollments; as a group, enrollments declined by 12 percent between 1969 and 1970. Such enrollments in the 14 largest public institutions, on the other hand, rose by 5 percent during the same time.[4]

Coincident with these recent declines in private institution enrollments were reductions in Federal R&D expenditures. Such funds declined by 8 percent (in constant dollars) between 1968-70 for private institutions, but remained essentially unchanged for public institutions. The magnitude of this decline is of considerable significance since 85 percent of research in private institutions is federally supported, compared with 65 percent for public institutions.[4]

While there are many factors affecting the growth and capacity of public and private institutions, a fundamental one appears to be the pervasive and worsening financial condition of these institutions.

Growth of Doctoral Programs: 1970-74

A survey was conducted by the American Council on Education of doctoral departments in science and engineering to determine the recent and probable future growth of doctoral programs.[5] The survey indicated that the ratio of net additions of such programs to existing doctoral departments was 1:26 during 1970-72. Plans for the 1972-74 period, however, indicate a reduction to 1:66, i.e., a net gain of one program per 66 existing departments. The largest net increases in 1970-72 were in the areas of computer sciences and psychology. Plans for 1972-74 indicate the greatest relative increase will again be in computer sciences.

RESEARCH EQUIPMENT AND FACILITIES

Research instrumentation and modern laboratories are basic tools of science. They provide man with his quantitative and most precise window on the real world. They permit the study of phenomena otherwise inaccessible to investigation, provide the means for accurate measurement and observation, and facilitate data collection and analysis. Sophisticated equipment is now a prerequisite for significant research advances in most fields of science. The excellent instrumentation available in the United States is generally regarded as a prime factor contributing to the leading position of American science. Since the requirements for instrumentation are constantly changing with progress in science, a continuing investment is necessary to maintain the quality of this basic tool.

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[4] Special tabulation based on data collected for the National Science Foundation report series, *Resources for Scientific Activities at Universities and Colleges.*

[5] National Science Foundation, *Science Resources Studies Highlights*, "Changes in Graduate Programs in Sciences and Engineering 1970-72 and 1972-74," July 21, 1972 (NSF 72-311).

The Federal Government is a prime source of support for research equipment and facilities. This includes basic laboratory equipment, as well as major equipment such as wind tunnels, accelerators, reactors, radio telescopes, etc., which are used for more than a single project, and R&D plant capital grants that fund the construction and maintenance of major R&D facilities.

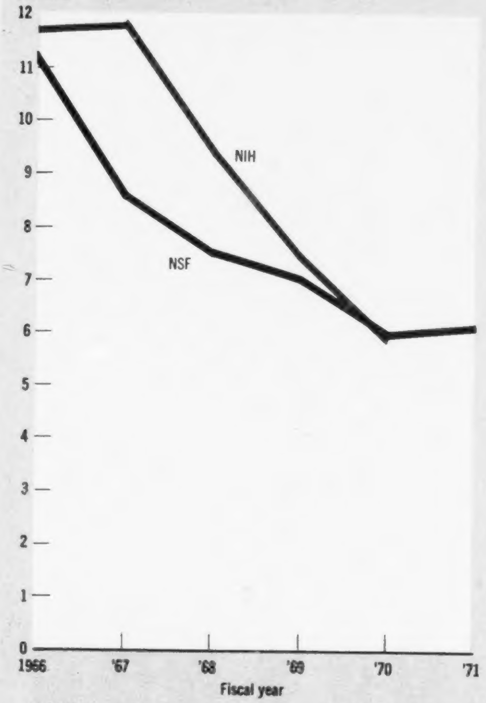
Research Equipment

A major source of laboratory apparatus for universities and colleges has been the Federal system of research grants, which have often included funds for laboratory equipment as part of the grants. Funds for research apparatus from this source declined in recent years, even though the overall grant funds increased. The extent of the decline is suggested by figure 59 which depicts the proportion of total project grant funds allocated for permanent research equipment. The data presented here are fragmentary in that only the National Science Foundation (NSF) and a part of the National Institutes of Health are included;[6] they are, however, major sources of research equipment funds and probably typify the situation in general.

This figure shows that as a proportion of total project grant funds, support for the purchase of permanent laboratory equipment declined by one-half—from nearly 12 percent to 6 percent—between 1966 and 1971. Funds for research grants, on the other hand, increased by about 15 percent over the same period.

Figure 59

Proportion of NSF and NIH[a] Research Project Grant Funds Allocated for Permanent Laboratory Equipment, FY 1966-71



(a) National Institute of General Medical Sciences and National Heart and Lung Diseases.

SOURCE: National Science Foundation.

In the case of the NSF, the reduced support for research equipment appears to have been absorbed largely by an upward shift in indirect costs, as shown in figure 60.[7] Salaries and wages, as a fraction of total grant funds, changed little during the period.

R&D Plant and Equipment

The Federal Government has been a prime source of support for major research equipment and R&D plant capital. However, Federal obligations to universities and colleges for new and improved R&D plant declined after the mid-1960's,

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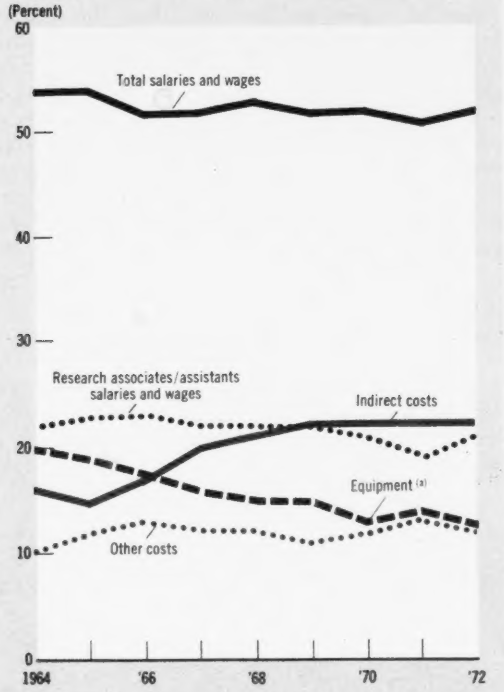
[6] National Institute of General Medical Sciences and National Heart and Lung Institute.

[7] The higher proportion of NSF grant funds for research equipment in figure 60, over that shown in figure 59, is due to the inclusion of funds for both permanent and expendable equipment in figure 60.

Figure 60

Distribution of NSF Research Project Funds, by Type of Expenditure, 1964-72



(a) Permanent and expendable equipment.

SOURCE: National Science Foundation.

falling by more than 75 percent between 1965 and 1971 (figure 61). Federal funds for R&D plant, as a fraction of total Federal obligations for academic science, declined from 8 to just over 1 percent during the same period (figure 61).

Since the effectiveness and, in many instances, the significance of research depends directly upon the availability of appropriate tools and plant, expenditures for them are as essential as expenditures for the performance of research itself. However, support for these critical items has fallen well behind that for research.

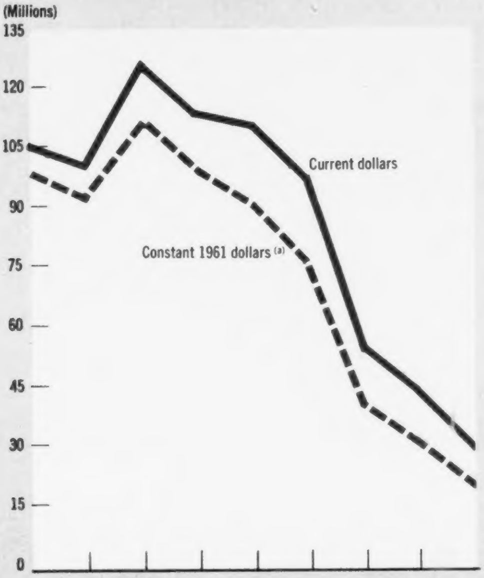
Major Research Facilities

Many fields of science now require large, specialized facilities to achieve significant advances and to initiate research in promising new

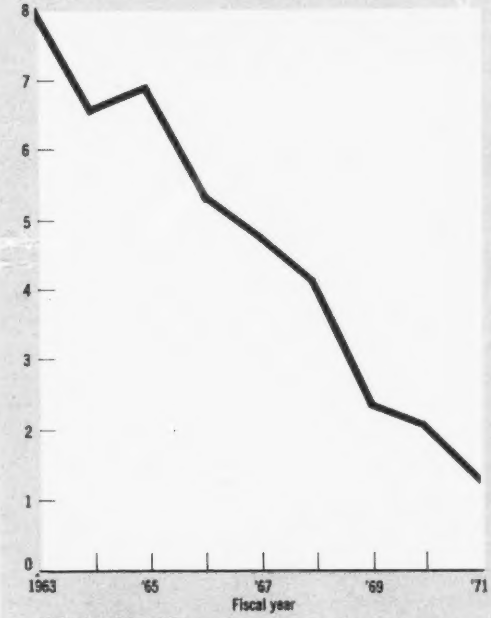
Figure 61

Federal Obligations for Academic R&D Plant, FY 1963-71

Total



As a percent of Federal obligations for academic science



(a) Based on academic R&D price deflator.

SOURCE: National Science Foundation.

areas. Until the authorization of the radio astronomy facility, known as the Very Large Array, in fiscal year 1973, no major research facilities—those requiring $5 million or more for construction—have been started since the Batavia accelerator in 1968. Yet nearly 30 new facilities have been proposed and evaluated as technically desirable and feasible in recent years. These are listed in the table below along with their estimated costs. There is an evident need for such facilities in many scientific fields—physics and astronomy, biology, and environmental sciences as well as engineering.

FEDERAL INTRAMURAL RESEARCH AND DEVELOPMENT

The Federal Government's R&D installations are engaged in a broad array of functions and activities, representing a significant portion of the national R&D effort. Organizationally and programmatically, each individual installation's orientation is primarily to the needs and mission of its parent or sponsoring agency.

Both in the Congress and in the general public, there is a perceptible view that the Federal laboratories should be more widely utilized in helping to solve current national problems. Although Federal agency missions, in one way or another, are oriented to meeting national needs and responsibilities, there are no national R&D installations which are independent of a particular executive branch agency for their programs, funding, personnel authorizations, and related essentials.

Number of Installations

Although an inventory of the security unclassified Federal R&D installations in 1969 listed a relatively large aggregate number of installations, there are only a few Federal

Technically Desirable and Feasible
Basic Research Facilities Costing $5.0 Million or More

Environmental Sciences	*Biological Sciences*	*Engineering*	*Physical Sciences*	
Upper Atmosphere Observatory ($14M)	National Resource Centers ($50M over 10 years)	Earthquake Engineering Facility ($30M)	NRAO VLA ($76M)	Upgrade 184" Synchrotron Berkeley ($7M)
NCAR 4th generation computer ($15M)	Brookhaven Center for Biological Instrumentation ($5M)	Automation Technology Institute ($5M)	Neroc 440' dia. Steerable ($30M)	Heavy Ion Lab for Nuclear Physics ($20M)
NOAA: Geophysical and Fluid Dynamics Laboratory computer ($18M)	Cell Production and Fractionation Centers ($25M over 5 years)	Engineering Software Technology Transfer Center ($8M)	Owens Valley Interferometer ($8M)	Array of Gravitational Detectors ($5M)
	National Institute of Ecology ($10M)	Resource Center for Construction and Industrialized Building ($6M)	100" Optical telescope ($5M)	Storage Ring Brookhaven Isabelle ($50M)
		Resource Center for Productivity and Machine Design ($6M)	200" Southern Hemisphere telescope ($20M)	Storage Ring Berkeley-Stanford ($75M) Project PEP
			NRAO Homology telescope	Recirculating Linear Accelerator Upgrade SLAC ($17M) Stanford
			Mountain Top Cosmic Ray Observatory ($5M)	
			Calculation Center for Chemistry ($10M)	
			Upgrade Cornell Electron Synchrotron ($5M)	

Source: National Science Foundation

agencies responsible for these installations.[8] A total of 17 departments, independent agencies, and commissions reported nearly 700 installations, over 85 percent of which are within the Departments of Agriculture, Defense, Interior, and Health, Education, and Welfare (HEW), and in the National Aeronautics and Space Administration (NASA).

Another feature of the Federal in-house R&D installations is the large number of small units; approximately one-half of all the installations have nine or fewer professional staff members. The majority of these installations are under the jurisdiction of the Department of Agriculture's Agricultural Research Service and Forest Service. Many of these small laboratories are actually in close juxtaposition to larger installations or are located on the campuses of land-grant institutions. At the other end of the size spectrum, the largest installations belong to NASA, and are staffed by almost 5,000 professionals.

Federal Funding of Intramural R&D

Cost data on Federal laboratories can be approximated from funding data on Federal intramural R&D. Such data have been collected since 1955, and include overall costs of Federal R&D performance as well as costs of administering R&D grants and contracts. In some agencies, such as the National Science Foundation which maintains no Federal laboratories, and the Atomic Energy Commission, which has only three relatively small laboratories, the costs of grant and contract administration represent the great bulk of the intramural effort. In others, such as the Department of Defense, the costs of administering grants and contracts are a minor portion of total intramural costs. This situation would also hold for NASA, and the Departments of Health, Education, and Welfare, Agriculture, Commerce, and Interior. Thus, funding data in this sector must be interpreted with considerable caution.

Between 1961 and 1972 Federal R&D obligations for intramural performance rose by a factor of two and one-third—from $1.9 billion to $4.5 billion—as Federal agency programs grew. In constant (1958) dollars the rise was not as steep—from $1.8 billion to $3.1 billion in 1972. Each year in the entire period marked a new high in current dollars, although between 1966 and 1969 the rise was very moderate and, in real terms, actually showed a slight decline (figure 62).

The rate of growth of Federal intramural R&D funding over the 1960-72 period exceeded that of the national R&D effort. During 1960, the Federal Government obligated $1.7 billion for intramural R&D which represented 23 percent of total Federal R&D obligations and 13 percent of total national R&D expenditures (figure 62). Estimates for 1972 indicate that Federal intramural R&D accounted for 27 percent of the Federal R&D budget and 16 percent of national R&D expenditures. Increases in the Federal intramural shares of R&D totals have resulted not only from higher intramural funding, but also from the fact that Federal funds for R&D in industry dropped in recent years, as the result of reductions in development programs of NASA and the Atomic Energy Commission.

Funding by Agencies

During this time, the Department of Defense (DOD) intramural R&D obligations were the largest of all agencies, although its share of the total of such Federal obligations decreased from 71 percent in 1961 to 54 percent in 1972 (figure 63). While the absolute level of DOD's intramural funding showed an almost continuous increase, the expansion of intramural work on the part of other agencies—notably NASA and HEW—was responsible for the decline in the DOD share.

NASA made up 10 percent of the Federal total in 1961 and rose to a high of 28 percent in 1965, reflecting the buildup of the Apollo program. Thereafter its share declined in most years, falling to 20 percent in 1972.

The Departments of Health, Education, and Welfare (especially the National Institutes of Health), Agriculture, Interior, and Commerce experienced little change over the 1961-73 period in their respective shares of Federal intramural R&D funding. Two of these agencies, Agriculture and Commerce, rely on intramural resources more fully than extramural performers, while the Interior Department does approximately one-half of its R&D intramurally.

The Department of Transportation did not come into existence until 1966, but its attention to problems of ground and air transportation

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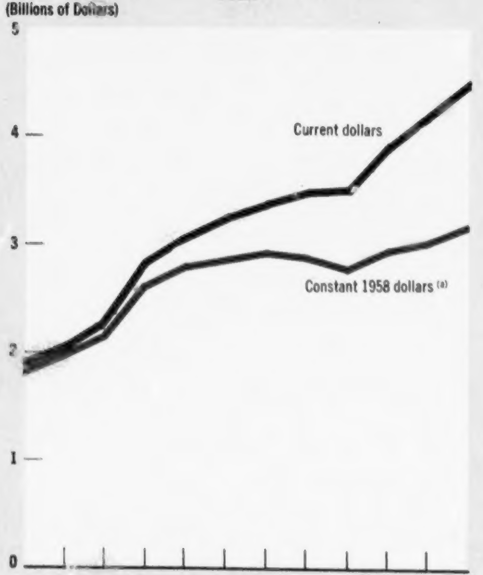
[8] National Science Foundation, *Directory of Federal R&D Installations*, NSF 70-23.

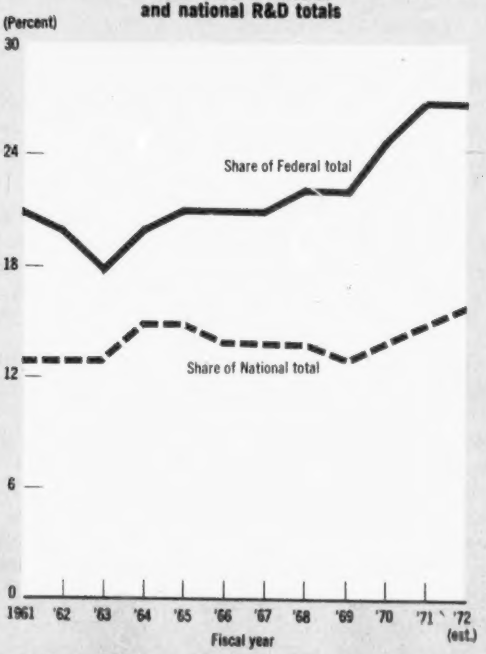
Figure 62

Federal Obligations for Intramural R&D Performance, FY 1961-72

Total



As a share of Federal and national R&D totals

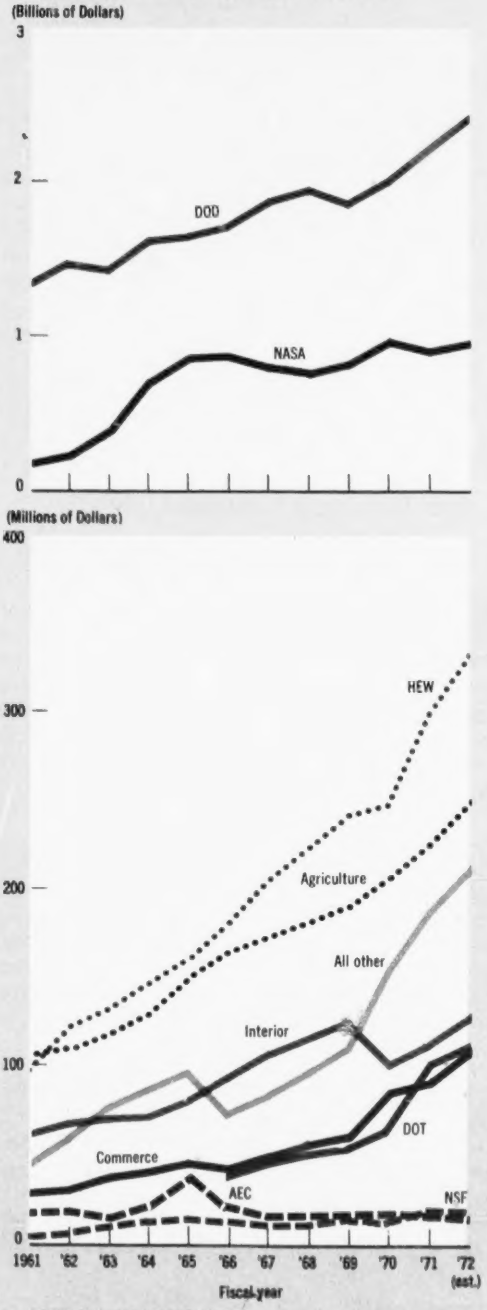


(a) GNP price deflator was used to convert current to constant dollars.

SOURCE: National Science Foundation.

Figure 63

Federal Obligations for Intramural R&D Performances, by Agency, FY 1961-72



SOURCE: National Science Foundation.

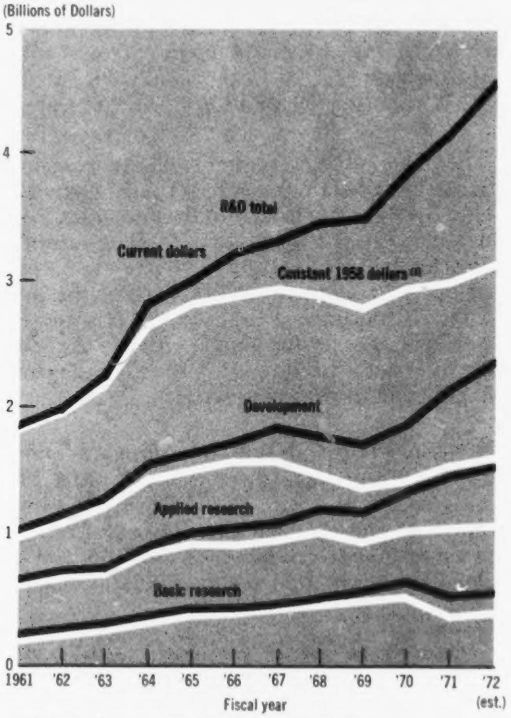
and traffic safety has been represented in increased R&D funding.

Character of Work

While development activities accounted for a considerable larger proportion of the Federal intramural total than either basic or applied research throughout the 1961-72 period, the fraction devoted to development declined from 55 percent in 1961 to an estimated 52 percent in 1972. Part of this decline was due to the Apollo program phaseout. Meanwhile, Federal intramural basic research increased from 11 percent to 13 percent of Federal intramural R&D funds, and applied research rose from 34 percent to 35 percent (figure 64).

Figure 64

Federal Obligations for Intramural R&D Performance, by Character of Work, FY 1961-72



(a) GNP price deflator was used to convert current to constant dollars.

SOURCE: National Science Foundation.

INDUSTRIAL RESEARCH AND DEVELOPMENT

Company Size and Research and Development

Research and development is an activity confined largely to large companies. The distribution of industrial R&D among different-size firms—as measured by the full-time-equivalent number of scientists and engineers engaged in R&D—is shown in figure 65. In 1971, 85 percent of all R&D scientists and engineers were employed by firms with more than 5,000 employees, as compared with 70 percent in 1958. Companies with fewer than 1,000 employees accounted for a declining proportion of industrial R&D scientists and engineers, from 20 percent in 1958 down to an estimated 6 percent in 1971. There was little change for companies of intermediate size.

The above statistics must be treated with caution. The structure of industry has changed over this period. "Research and development," as an industrial activity, was in its early stages of growth during the 1950's. While the number of companies with 5,000 or more employees grew by about 50 percent between 1958 and 1967, the number of firms with less than 1,000 employees actually declined slightly. Some small companies naturally grew in size; others were absorbed by larger corporations. A further reason for caution in interpreting these data is the quality of respondent reporting, especially for small companies, during the early years of the survey.

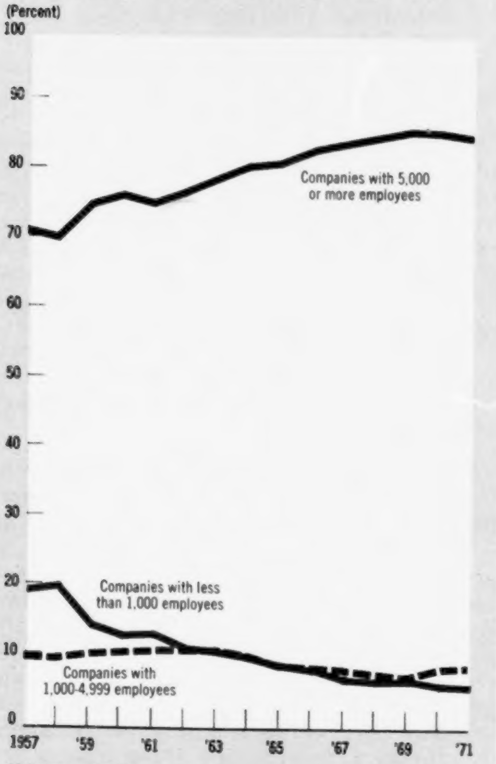
Despite these cautions the rapid apparent decline of R&D in small firms may be a danger signal which calls for further investigation to determine its true significance. There is ample historical evidence to suggest that small firms have produced more than a proportionate share of major innovations, particularly those innovations which have been one of a family of successive innovations whose cumulative effect has been to create an entirely new industry. It is possible that the statistics quoted here do not accurately represent the true situation, but it is also possible that they signal a declining rate of technological innovation.

R&D Intensiveness

An indication of the degree of "R&D intensiveness" of an industry is the proportion

Figure 65

Distribution of Industrial R&D Scientists and Engineers,[a] by Company Size, 1957-71



(a) Full-time equivalent.

SOURCE: National Science Foundation.

of the total human and financial resources which it invests in R&D. A high level of R&D, however, does not necessarily insure that an industry is highly innovative. For example, an industry may direct its R&D activities toward product differentiation, rather than to more basic technological innovation.

Two frequently used indicators of R&D intensiveness are (a) the number of R&D scientists and engineers as a percentage of all employees, and (b) the percent of net sales devoted to R&D. These indicators are used in the following to estimate the level of R&D intensiveness of U.S. industry as a whole, as well as of manufacturing and nonmanufacturing industries, and to determine its relationship to company size.

U.S. Industry. The first of these indicators shows that for U.S. industry as a whole, the number of R&D scientists and engineers increased from 25 per 1,000 employees in 1960 to 30 in 1964-65, but then declined to 24 in 1970. Similarly, the percent of net sales devoted to R&D rose from 4.2 in 1960 to 4.6 in 1964, and then declined progressively to 3.8 in 1970 (figure 66).

The changes between 1960-70 in both indicators show that the R&D intensiveness of U.S. industry, in terms of scientific and engineering manpower, increased by 20 percent between 1960-64 but then declined to a level in 1970 which was lower than 1960. The percent of net sales shows the same trend; the ratio rose by almost 10 percent between 1960-64 and then fell continuously to a level in 1970 well below that of 1960.

Manufacturing Industries. Individual manufacturing industries differ greatly in the extent of their R&D intensiveness. Based on the two indicators, each of the 15 major industries in the manufacturing sector was placed into one of three groups according to the level of its R&D intensiveness in 1970. The resulting groups, each consisting of five industries, are presented in the table on page 79; Group I industries are the most R&D intensive and Group III the least.

The level of R&D intensiveness remained essentially constant for industries in Groups II and III between 1960-70, but declined for Group I industries after 1964 (figure 67). The extent of the latter reduction was approximately 25 percent by 1970, as measured by each of the indicators. The declines in the most R&D-intensive group appear to be due almost entirely to reductions in Federal funding of defense- and space-related R&D in these industries.

Nonmanufacturing Industries.[9] Only a small number of companies (estimated at 1,100-1,200) in this sector perform R&D. The R&D intensiveness of those which perform any R&D increased by 50 percent between 1961-66, and remained at essentially that level in later years.[10]

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[9] These include (but are not limited to) agriculture, mining, transportation, public utilities and sanitary services, wholesale and retail trade, finance, insurance, business services, medical and dental laboratories, and engineering and architectural services.

[10] National Science Foundation, *Research and Development in Industry, 1970* (NSF 72-309).

R&D Intensiveness of Manufacturing Industries

	R&D scientists and engineers per 1,000 employees, 1970	*Percent net sales devoted to R&D, 1970*
Group I		
Chemicals & Allied Products	38	4.1
Machinery	28	4.2
Electrical Equipment & Communications	39	7.5
Aircraft & Missiles	74	18.3
Professional & Scientific Instruments	31	5.9
Mean	42.0	8.0
Group II		
Petroleum Refining & Extraction	18	1.1
Rubber Products	18	2.1
Stone, Clay, & Glass Products	14	1.9
Fabricated Metal Products	10	1.2
Motor Vehicles & Other Transportation Equipment	20	3.5
Mean	16.0	2.0
Group III		
Food & Kindred Products	6	0.4
Textiles & Apparel	4	0.5
Lumber, Wood Products, & Furniture	4	0.4
Paper & Applied Products	6	0.7
Primary Metals	6	0.8
Mean	5.2	0.6

Source: National Science Foundation, *Research and Development in Industry, 1970.* (NSF 72-309).

(Data for the percent of net sales devoted to R&D are not available.) This places nonmanufacturing industries between Groups II and III of the manufacturing industries with respect to R&D intensiveness.

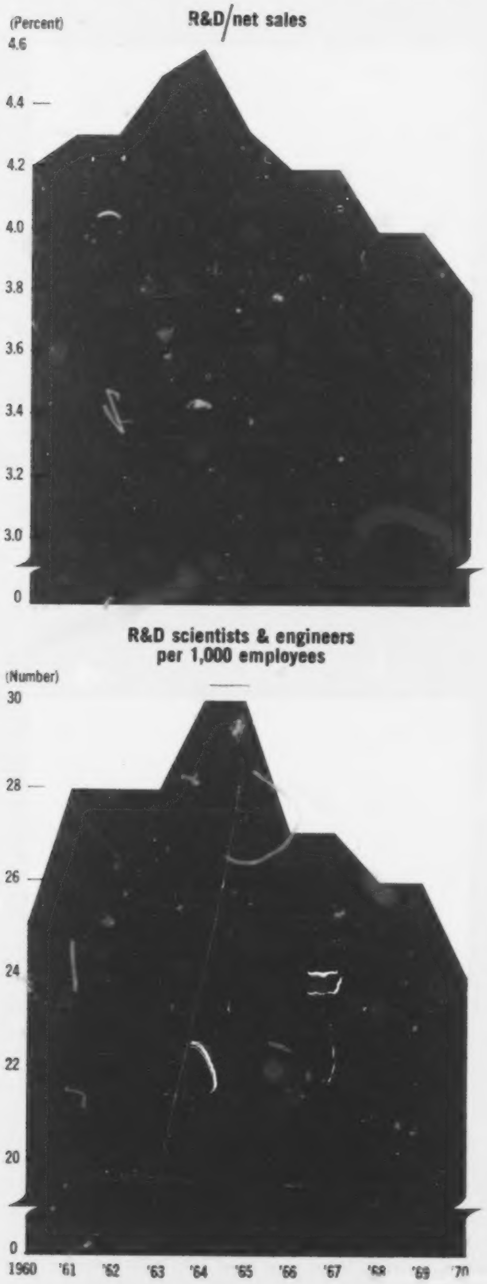
Company Size and R&D Intensiveness. Larger companies invested proportionally more of their resources in R&D than smaller ones over the period for which comparable data are available (figure 68). Very large companies (10,000 or more employees) devoted 4 to 5 percent of their net sales to R&D in 1967 and 1970, as compared with some 2 percent for smaller companies in 1967. The smallest companies (less than 1,000 employees), however, had almost the same ratio of R&D scientists and engineers to total employees as the largest companies in 1967. This ratio declined significantly in the largest companies between 1967-70.

Concentration of Industrial R&D

One of the most salient features of R&D in this sector is its high concentration within a few industries within the manufacturing sector. In 1970, 81 percent of industrial R&D funds were spent by five industries: aircraft and missiles (29 percent); electrical equipment and communications (24 percent); chemical and allied products (10 percent); machinery (10 percent); and motor vehicles and other transportation equipment (8 percent). Yet together these industries account for less than one-half of total manufacturing sales. This pattern of concentration developed in the 1950's and continued with little change through the 1960's. Since 1963, however, there has been a continuous but small (5 percent) reduction in the concentration. This shift is primarily due to declining expenditures for R&D related to aircraft and missile development, and

Figure 66

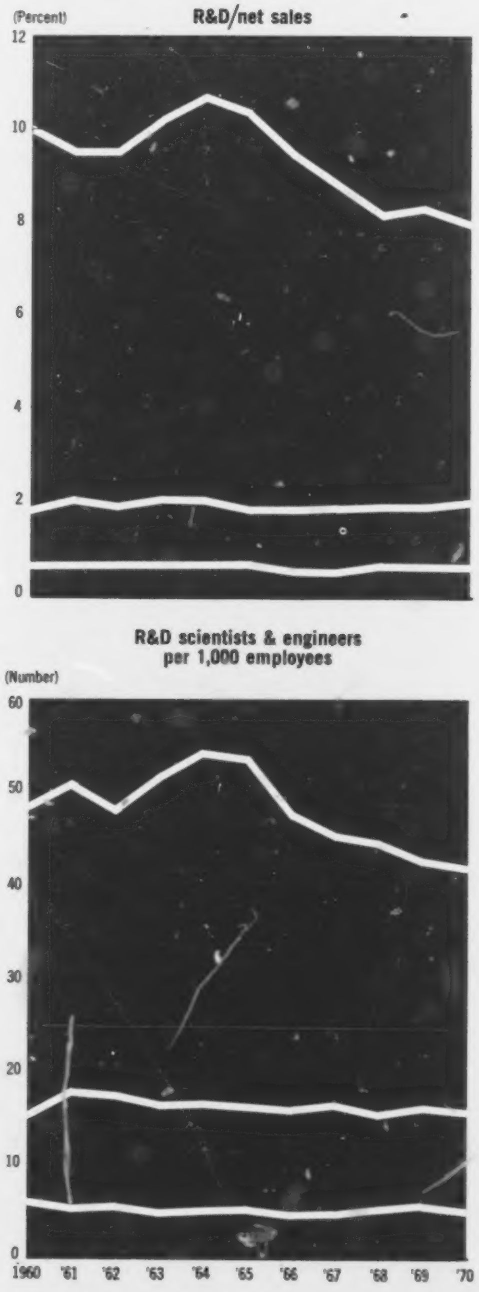
R&D Intensiveness of U.S. Industry, 1960-70



SOURCE: National Science Foundation.

Figure 67

R&D Intensiveness of Groups of Manufacturing Industries, 1960-70



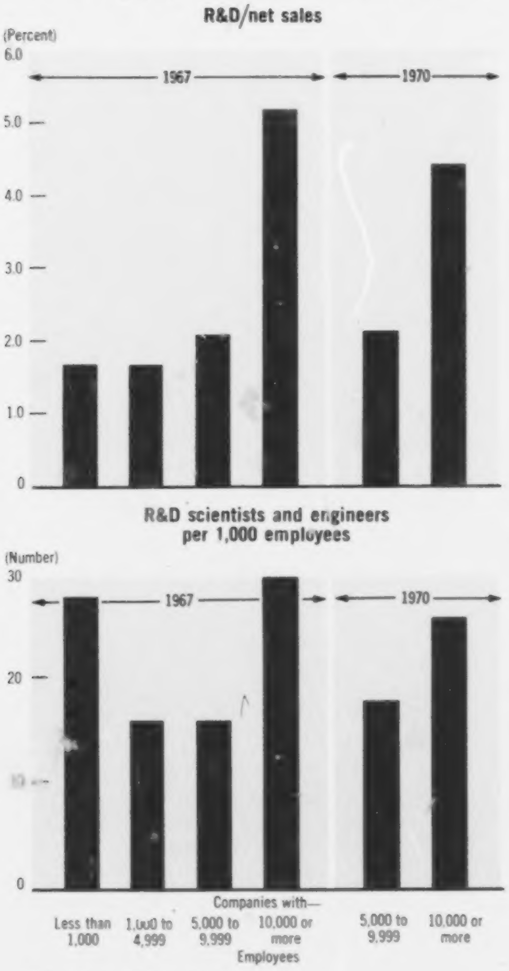
SOURCE: National Science Foundation.

to a lesser extent, to the increasing R&D in industries other than the five noted above.

Industrial R&D in these manufacturing industries is also heavily concentrated in a relatively small number of companies. The four companies having the largest R&D investment spent 18 percent of all industrial R&D funds in 1970; the largest 20 spent 55 percent; and the largest 100 spent 79 percent. Some 300 companies spent 91 percent of all funds for industrial R&D. This pattern changed little over the past decades. This concentration, however, partially reflects the fact that certain industries, particularly some of those which are most R&D intensive (e.g., aircraft and missiles), are largely comprised of a relatively small number of large companies. R&D in such industries tends, perforce, to be concentrated in these large companies.

Figure 68

R&D Intensiveness in Manufacturing Industries, by Company Size, 1967 and 1970



SOURCE: National Science Foundation.

A Delphi Experiment

A Delphi Experiment

■ Various aspects of the scientific-technological enterprise and external conditions that influence its capabilities and performance are not amenable to purely quantitative treatment. Some of these were explored through a public opinion survey, the results of which are summarized in the following section of this report. Others involve considerations of a predominately scientific or technical nature. Several of the latter aspects and conditions were investigated on an experimental basis, using a Delphi technique to solicit and synthesize the judgments and opinions of a cross section of the scientific and technological community. The study was carried out over the period of July-August 1972.

The topics explored in this experimental effort were:

Panel 1—The future role of science and technology in areas of high public concern;

Panel 2—Impacts of recent R&D funding changes on science and technology;

Panel 3—Technologial innovation including current impediments and measures for enhancement;

Panel 4—Basic research including criteria for support and means for improving its effectiveness;

Panel 5—Allocation of financial resources among fields of scientific research; and

Panel 6—Future directions for graduate education in science and engineering.

Participants in the Delphi exercise, who are listed in Appendix B, were selected for their extensive experience and knowledge in science and technology and the interaction of the two with society. Panels, ranging in size from 10 to 42, were composed of participants encompassing the disciplines, experience, and institutions relevant to the specific topics. Panelists represented a broad spectrum of disciplines (physical, life, and social sciences and engineering); experience (management, research, teaching); and institutions (colleges and universities, foundations, government, and industry).

The Delphi technique used in this experiment solicited the judgments of the participants through a relatively structured set of questions organized into two rounds. In responding to the first round of questions each participant was invited to suggest additional aspects and questions either to attain greater detail or to expand the scope of the topic. The second round incorporated these suggestions, provided feedback to each participant of both his first-round responses and those of the panel as a whole, and extended the questions. Participants in the second round responded again to the first-round questions—altering their initial responses if desired, in light of the group responses and suggestions—as well as to the questions added between rounds one and two. The second-round responses to panels reported hereafter are aggregates of the individual responses, with each participant contributing equally to the collective judgment.

The Delphi methodology used in this experiment had both merits and shortcomings for the purposes of this effort. On the positive side, it proved to be a relatively efficient means for obtaining the collective judgment of a large number of respondents, under conditions which encouraged the expression of individual viewpoints free from the pressures of face-to-face encounters. As used here, however, the technique had some serious weaknesses: the size of some of the panels may have been too small to represent the variety of viewpoints associated with some topics; and the controlled and limited nature of the inquiry may have resulted in misinterpretation of certain questions, as well as difficulties in responding to them. Posing questions about inherently complex and subtle issues in the most appropriate way was often the most difficult, and least successful, aspect of the experiment.

Finally, it should be noted that panelists responded to three different kinds of questions: questions soliciting cause or effect *interpretations;* questions soliciting *predictions;* and questions soliciting *recommendations* about possible future policies. Although expert judgment is involved in each case, interpretations and predictions differ from recommendations in that the latter involve normative considerations to a greater extent. Furthermore, in the absence of comparable previous studies the results should be interpreted with caution. They are presented in this report in the same spirit as that in which they were obtained: as experimental findings.

The judgments of the panelists are summarized in the following pages. Only those judgments expressed by the panels as a whole are presented. This omits the many interesting comments and suggestions provided by individual participants but which were not reviewed by the entire panel.

DELPHI TOPICS

Panel 1—42 Panelists

National Problems Warranting Greater R&D

Panelists judged the extent to which science and technology could help ameliorate several problems of high public concern and identified the areas in which expanded R&D was warranted. These judgments are presented in table A.

Although R&D was viewed as essential for alleviating many of the Nation's problems, it was rarely regarded as sufficient in itself. The full effectiveness of science and technology was seen as dependent upon appropriate social, economic, and political policies.

A number of problem areas identified by the Delphi panelists as warranting expanded R&D were the same areas as those chosen by the general public for applications of science and technology.[1] The areas in common which were most favored by the public were health care, pollution control, drug abuse, and crime.

Table A—National Problems Warranting Greater R&D Effort

Problem area[1]	*Areas which could benefit from science and technology (percent of panelists)*	*Areas warranting major increases in R&D (percent of panelists)*
Pollution (including water pollution, solid waste disposal, land pollution	97	92
Power/energy resources (including greater conservation and more efficient use of power resources)	97	86
Industrial productivity	81	70
Adequacy of natural resources	80	82
High cost and ineffectiveness of health services	79	86
Deterioration of international economic position of the United States	66	68
Population growth	56	53
Inappropriateness and expense of education	50	62
Magnitude, quality, and delivery of information	47	40
Drug abuse	46	70
Inadequate urban planning	45	63
Poverty	43	56
Breakdown in efficiency and innovativeness of public sector services	36	48
Inadequate employment opportunities	28	47
Nuclear war	27	34
Urban crime	23	46
Disrepect for established institutions	8	17
Group conflict and alienation	8	33
Irresolution of international conflict	8	32
Changing values (sex mores, work ethics, etc.)	3	12
Racial discrimination	3	31

[1] Items in italics were suggested to panelists as examples; others were added by panelists and presented in the second round.

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[1] See the following section, "Public Attitudes Toward Science and Technology."

Panel 2—16 Panelists

Impacts of R&D Funding Changes

Delphi panelists identified and assessed certain R&D funding changes which had occurred since 1965 in terms of their beneficial or detrimental impacts, and identified some of the major consequences—both positive and negative—of these changes. Funding changes, which a majority of panelists believed to be either beneficial or detrimental, are presented in table B.

Table B—Funding Changes Assessed as Beneficial or Detrimental to R&D

Beneficial changes[1]	*Percent of panelists assessing change as beneficial*
Increased spending for health related R&D	69
Increased support for social sciences	67
Increasing percentage of total R&D funded by industry rather than Government	65

Detrimental changes[1]	*Percent of panelists assessing change as detrimental*
Decreased R&D funding (in constant dollars)	100
Frequent rapid changes of programs and directions of funding	100
Decrease (in constant dollars) in basic research funds	95
Allocation of funds by student count	82
Closing down or significantly diminishing support for some large industrial R&D laboratories	81
Decrease in R&D activities of small firms	67
Reduction in rate of initiation of construction of "Big Science" facilities	66
Increased allocation to R&D areas with short-term application	52

[1] Items in italics were suggested to panelists as examples; others were added by panelists and presented in the second round.

Three changes in R&D funding were viewed as beneficial. Increased spending for health-related research and development was regarded as having been a positive trend because of the likelihood of improved health services for the general community, rather than for basic science advances in the life sciences per se. Similarly, increased support for the social sciences were deemed beneficial largely because of the possibilities for developing a more scientific approach to social problems; increased R&D funding by the private sector was seen as probably resulting in greater emphasis on efforts which contribute to the economy in significant and immediate ways. Some panelists, however, warned that the latter change produced a shift in R&D toward short-term and low-risk efforts aimed at insignificant technological advances.

Most of the changes regarded as detrimental relate to decreases in R&D funding. In respect to reduced R&D and basic research funding (in constant dollars), the many consequences suggested by individual panelists included: a decrease or delay in developing new knowledge; the loss of scientific manpower and the reduction of the number of future scientists and engineers; increased reliance on Federal administrators for program selection; the demise of significant basic research programs formerly supported by the Department of Defense; and in the long run, a loss of the U.S. leadership position in basic sciences.

As in the case of funding decreases, all panelists judged frequent, rapid changes of programs and directions of funding to be detrimental because of the discontinuities introduced into research programs and the consequent waste of financial and human resources.

The panelists also registered concern about criteria employed in allocating support for research. The group thought that allocation on the basis of "student count" (a funding change identified by the panelists) was detrimental to the scientific and technical enterprise since it results in an ever greater concentration of research in larger institutions. A small majority (52 percent) of the panelists believed that increased allocation to R&D areas with short-term application was harmful because of the resulting reduced support and training in the basic sciences; a slower rate of development of new knowledge; the sacrifice of long-term needs; and increased support of second-rate projects masked as topical and relevant research. In contrast, 25 percent of the respondents thought that increased allocation to areas with short-term application was beneficial because of possibly earlier benefits to society in important need areas.

The R&D efforts of industry were also a prime concern of the panelists, who thought that decreased support for some large industrial R&D laboratories were detrimental to science and technology. The panelists related this funding change to decreases in productivity and in beneficial technological advance, and weakening of the international trade position of the United States. The group (76 percent) also rated the effects of a decrease in R&D activities of small firms as detrimental. They warned against the loss of important innovative groups and the technical obsolescence of small firms. However, 40 percent of the panelists believed the unfavorable consequences would be minimal because significant advances require greater capabilities than are usually available to small firms.

Finally, the panel registered mixed reactions to the reduced rate of initiation of construction of "Big Science" facilities. The majority of panelists viewed the change as detrimental, and related it to a decrease in the rate of discovery in the long run, decline in the rate of research activity, and loss of international scientific leadership.

Panel 3—14 Panelists

Changes Needed to Improve Technological Innovation and Diffusion

This examination attempts to identify major impediments to technological innovation and diffusion in this country, and actions which might be taken to improve the situation. The impediments of both types suggested by the panel are presented in table C.

The major impediments to technological innovation which the group identified can be grouped into three areas related to (a) incentives and government policies, (b) industrial management, and (c) research activities and manpower. Some of the suggested factors, however, were regarded as beneficial by several of the panelists, including patent policies which inhibit innovation (25 percent); lack of a government agency to support the introduction of technological innovation (18 percent); and antitrust laws which prohibit cooperative ventures (17 percent).

Major impediments to the diffusion of innovations can be grouped into (a) lack of financial incentives and characteristics of the market for innovative products and services, (b) policies and practices of industry itself, and (c) human resources. Several panelists evaluated the suggested factors as actually beneficial including: oversized, overorganized industry (22 percent); lack of a government agency to support the introduction of technological innovation (18 percent); and antitrust laws which prohibit cooperative ventures (17 percent).

Panel 4—12 Panelists

Adequacy of Current Basic Research Efforts

This inquiry assessed the appropriateness of the total funding level for basic research in terms of:

(a) Criteria considered to be important in determining an appropriate funding level for basic research, and the appropriateness of the current level on the basis of these criteria,

(b) Propensity for "risk-taking" in potentially "high-payoff" areas of research, and

(c) Factors perceived to be impeding basic research in general.

Criteria for Support of Basic Research

The panelists emphasized the significance of both external factors and the opportunities and needs of the scientific enterprise itself, in determining an appropriate funding level for basic research (table D). Using these criteria, they suggested moderate increases, ranging from 2 to 12 percent, over the 1972 funding levels. The average of the proposed increases would raise the total funding in current dollars to $4.4 billion in 1973.

High Risk-High Payoff Research

The panelists also evaluated the adequacy of basic research efforts by assessing the propensity to undertake "high risk-high payoff" basic research. "High risk-high payoff" basic research refers to projects which may have a low probability of producing results and yet promise results, if achieved, of such significance that the projects are deemed worth the risk. An example

Table C—Factors Impeding Technological Innovation and Diffusion

Impeding Factors[1]	*Percentage of panelists rating factor as impediment to:*	
	Innovation	*Diffusion*
Incentives and Government Policies		
Inadequate profit from innovative work to help social sector problems	100	100
Disaggregated and diffused market in several sectors needing innovation (local government, housing, health services, etc.)	100	91
Inability to obtain venture capital funds for high-risk innovations	92	77
Lack of appropriate tax incentives for R&D and innovation	91	72
Limited Federal support of industrial projects with high social return but low private return	82	73
Negative public attitudes toward technology	82	63
Antitrust laws which prohibit cooperative ventures	75	75
Lack of a government agency to support the introduction of technological innovation (to offset role of regulatory agencies)	55	55
Patent policies which inhibit innovation	33	38
Industrial Management		
Reluctance to abandon commitment to current processes/products	100	100
Limited industrial research budgets	92	84
Lack of orientation of R&D toward needs	91	100
Limited understanding of the innovation process by big company management	91	91
Lack of acceptance of innovations developed elsewhere	91	90
Lack of entrepreneurial spirit	73	91
Oversized, overorganized industry	56	56
Lack of adequate business and marketing efforts (to exploit successful innovations)	56	56
Research Activities and Manpower		
Negative bias of academic scientists toward the value of industrial research	100	80
Insufficient exploratory research	100	60
Education of scientists and engineers inappropriate for innovation	92	75
Lack of national priorities to focus science and technology resources	91	82
Negative attitude of academic scientists toward programmed (goal directed) research and multidisciplinary team research management	89	78
Lack of new ideas stemming from basic research	85	23
Lack of necessary technical skills	75	100
Limitations in the diffusion of technical information (in English and in foreign languages)	67	75

[1] Items in italics were suggested to panelists as examples; others were added by panelists and presented in the second round.

Table D—Criteria for Use in Determining Total Funding Levels for Basic Research

Criteria[1]	*Importance* *Very important (4) percent*	*(3) percent*	*(2) percent*	*(1) percent*	*Unimportant (0) percent*	*Relative importance*[2]
Potential for fundamental new insights	58	33	8	0	0	1.00
Science needed to generate technological solutions to major societal needs	45	36	17	0	0	.95
Contributes to maintenance of adequate spectrum of basic research skills as a resource for the future	33	42	25	0	0	.91
Availability of resources in society: ratio of total basic research/GNP	33	50	0	8	8	.87
Number of qualified researchers	25	33	33	8	0	.83
Proposal pressures: quantity of meritorious proposals in particular areas of basic research	33	17	42	0	8	.82
Predetermined ratio of basic research to total R&D expenditures	33	17	25	25	0	.80
New application of known laws to broader range of problems and initiatives	25	17	25	33	0	.76
Research contributes to education and training of new researchers	0	50	25	25	0	.73
Competitive pressure: activity of greater emphasis existing in other nations	17	17	17	33	17	.64

[1] Items in italics were suggested to panelists as examples; others were added by panelists and presented in second round.

[2] Sum of importance ratings for each criterion (proportion of panelists selecting each importance category times the numerical value of the category), divided by the largest sum.

of such work might be the current search for gravitational waves.

The panelists judged the level of "high risk-high payoff" basic research to be increasingly inadequate over the 1968-72 period. This decline was attributed to overall economic factors, lack of understanding of the process of discovery, and general disaffection with technology, as shown in table E.

Ninety percent of the panelists agreed that the economic recession forced an emphasis on short-term payoffs to the detriment of "high risk-high payoff" research. Sixty percent believed the increasing high cost of basic research ventures heightened these effects. To reverse the trend toward less "high risk-high payoff" research, panelists (64 percent) suggested establishing long-range research objectives, providing incentive risk-support funding (44 percent), and increasing Federal funding to basic research in universities (38 percent).

Eighty percent of the panelists thought that lack of understanding of the process of discovery caused a change in the ratio of funding for "high risk-high payoff" basic research. They called for making the "hard and unpopular" decision to retain a fraction of resources for high-risk research (67 percent) and for recognizing the role of the scientist—as distinct from the engineer—in industrial research (40 percent).

Relatedly, 89 percent of the respondents believed that public and, therefore, political disaffection with perceived societal effects of technology contributed to the decline in high-risk funding. Similarly, 70 percent thought disappointment with payoffs from previous research investment was partially responsible for the decline. Sixty-three percent also expressed

Table E—Possible Causes for Relatively Reduced Support of High Risk-High Payoff Research

Suggested causes[1]	*Percent of panelists in agreement*
Economic recession forced emphasis on short-term economic payoff, and concomitant retreat of scientists to safe areas of research	90
Public and political disaffection with perceived societal effects of technology	89
Lack of understanding of process of discovery	80
Disappointment with payoff from research investments (i.e., space, high energy physics, etc.)	70
Association of R&D with the Defense Department, and transfer of negative feelings about military expenditures	63
Increasingly high cost of basic research ventures	60
Failure to handle accelerating pace of knowledge acquisition	43
Investment in mission-oriented space research	29

[1] Items were suggested by panelists in the first round, and presented in second.

the belief that association with the Department of Defense results in the transfer of negative feelings regarding military expenditures to all R&D activities. Compensating policies included educating the public about the positive role of science and technology in the solution of societal problems (60 percent); direct funding of payoff areas (i.e., ecology, nuclear fusion, oceanography) (56 percent); administration of all Federal contracts through civilian agencies (50 percent); promoting public awareness of differences between science and technology (44 percent); and operationalizing and publicizing systems of technology assessment (38 percent). Seventy-one percent of the panelists disagreed that investment in mission-oriented space research caused a decline in "high risk-high payoff" basic research.

Impediments to Basic Research

Finally, panelists evaluated factors which may be impeding the effectiveness of basic research (table F). These factors can be grouped approximately as: (a) *external factors* relating chiefly to funding, including the level of funding, the source and criteria for funding, and knowledge and attitude of the public; and (b) *internal factors* including inadequate long-range planning, "fashions" in research, inadequately trained researchers, lack of equipment, and inadequate industrial participation.

Several panelists thought some of the factors were not impediments. Fifty-six percent of the group judged the current number of researchers to be adequate; 63 percent believed that emphasis on applied research had essentially no effect or actually helped; 50 percent thought the composition of science advisory groups was not an impediment; and 27 percent viewed funding through national defense agencies as beneficial.

Panel 5—33 Panelists

Distribution of Basic Research Funds Among Fields of Science

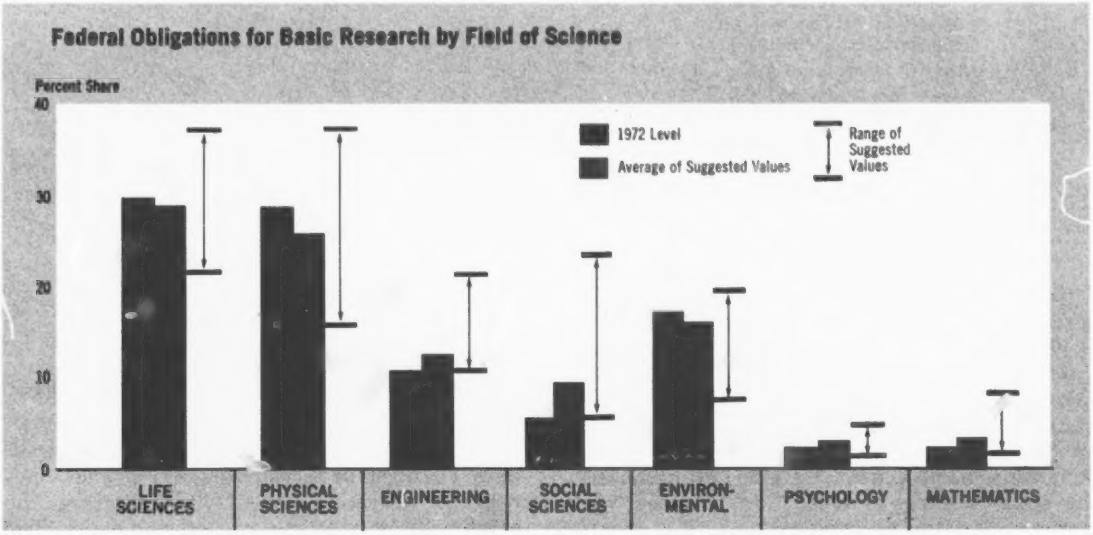
Under this topic opinions were sought about criteria which might be useful in deciding on relative levels of support for basic research in various scientific fields—life, physical, engineering, mathematical, and social. The several criteria suggested by the panelists (table G) can be separated into four clusters, each reflecting a dominant concern: (a) advancement of knowledge (Nos. 1, 2, 4, 6, 7, 11); (b) effective use of scientific capabilities and resources (Nos. 10, 14, 15, 16, 18); (c) potential application and use of results (Nos. 3, 5, 8, 9); and (d) public understanding and support of research (Nos. 12 and 17). In terms of the importance ratings assigned by the panelists to the criteria in each cluster, allocation of funds among fields should depend primarily upon opportunities for advancement of knowledge and the potential application of this knowledge to practical ends. Of much less importance—but still to be considered—are criteria concerned with effective use of scientific capabilities and resources, and public understanding and support of basic research.

Using these criteria, the panelists evaluated the appropriateness of the present distribution of research funds among fields, with the results shown in the figure entitled "Federal Obligations for Basic Research by Field of Science."

Table F—Impediments to Basic Research

Factors which may be impeding the effectiveness of basic research in the U.S.[1]	*Percent of panelists* *Completely halts basic research*	*Seriously impedes basic research*	*Somewhat impedes basic research*	*Has essentially no effect*	*Actually helps basic research*
Inadequate funding level		80	20		
Lack of long-range scientific planning		75	17		8
"Fashions" in selecting areas for support		73	18	9	
"Fashions" in research		73	18	9	
Emphasis on near-term payoff		73	18		9
Lack of public understanding of role of basic research		73	27		
Inadequately trained researchers	11	55	11	22	
Lack of research equipment		64	27	9	
Inbreeding in the socio-political structure of science advisory groups		40	10	40	10
Emphasis on applied research		36		36	27
Inadequate industrial participation		36	64		
Short-term funding of research projects		36	55	9	
Inadequate number of researchers		33	11	56	
Funding by defense agencies		27	45		27
Research perceived as socially undesirable		18	73	9	

[1] Items in italics were suggested to panelists as examples; others were added by panelists and presented in the second round.



Federal Obligations for Basic Research by Field of Science

Table G—Criteria for Allocating Basic Research Funds Among Scientific Fields

Criteria[1]	Importance Very important (4)	(3)	(2)	(1)	Unimportant (0)	Relative importance[2]
	Percent	Percent	Percent	Percent	Percent	
Potential for major extension of scientific knowledge	42	42	17	0	0	1.00
Basic knowledge to be gained in the field promises to provide new directions for science	8	67	25	0	0	.97
Likely payoff for national objectives, such as health, defense environmental controls	83	0	24	16	0	.92
Extent to which field is ripe for growth	25	42	33	0	0	.88
Field stimulates new technological advances	27	36	27	9	0	.81
Field contributes to progress in other fields	8	75	8	8	0	.81
Fields that create new disciplines	0	50	25	0	25	.69
Market mechanism indicates more research is necessary	10	40	40	10	0	.68
Field contributes to national educational objectives	0	42	17	42	0	.66
Field attracts the most able researchers	17	42	8	17	17	.65
Maintaining balance of research competence across fields	0	20	30	40	10	.64
Fosters public understanding of basic research	18	9	54	9	9	.63
Superiority of internal (Nos. 1, 2, 4) over external (Nos. 3, 5, 8) criteria	0	30	10	50	20	.61
Extent of effective use of resources in field	0	25	33	25	17	.59
Balance between current and anticipated demands for persons trained in field	0	27	36	27	9	.58
Number of researchers working in field without adequate support	0	18	18	45	18	.58
Packaging of basic research programs so as to enhance political support	0	9	27	54	9	.53
Unit cost of doing research	0	8	42	25	25	.47
Need to match facilities being constructed or in use in other countries	0	17	8	75	0	.35

[1] Items in italics were suggested to panelists as examples; others were added by panelists and presented in second round.

[2] Sum of importance ratings for each criteria (proportion of panelists selecting each importance category times the numerical value of the category), divided by the largest sum.

Comments by panelists, however, suggest certain ambiguities in the phrasing of instructions and questions which allow several possible interpretations concerning the total basic research level and time frame referred to by the questions. These ambiguities, however, do not invalidate the panelists' general suggestion for increasing the proportionate level of funding for the social sciences as well as for engineering, mathematics, and psychology.

Panel 6—10 Panelists

Changes in Graduate Training of Scientists and Engineers

This Delphi study sought to identify and evaluate changes in graduate science and engineering education aimed at increasing the employability of scientists and engineers. The panel assessed the importance of these changes in terms of their effects on the graduate's ability to find employment and to contribute over a period of time to his profession.

The changes identified by the panelists (table H) emphasized the need for (a) individualized training, (b) integrating work and education, and (c) reducing the extent of specialization. Better guidance in career development and midcareer education were seen as most important to lifelong professional effectiveness of scientists and engineers. As for employability, increased use of cooperative and multidisciplinary research along with independent, practice-oriented programs were rated as possible significant improvements.

Table H—Evaluation of Changes in Graduate Education

Currently or potentially important graduate educational changes[1]	*Percent of panelists indicating that change would:* *Improve employability*	*Improve professional effectiveness*	*be implemented by 1980*
Increased use of cooperative programs	98	78	67
Increased emphasis on accrediting practice-oriented graduate programs	90	60	60
Increased emphasis on "multi-disciplinary research"	89	70	90
Establishment of personalized or independent graduate programs	89	78	67
Greatly improved systems for assembly and access to current information on science and technology	89	89	50
Better guidance in career development	89	100	55
Inclusion of additional year of "intern" training in a non-academic institution as part of degree requirements	80	50	10
Expansion of programs conferring joint degrees (e.g., M.S. in chemistry: M.A. in business administration)	80	60	50
Establishment of a two-track (practice oriented, research) graduate program with different requirements for masters and doctorate degrees	80	60	50
Relate educational programs and professional experience by encouraging faculty involvement in both	80	67	30
Increased emphasis on "team" research in curricula concerned with highly specialized fields	70	70	60
Emphasis on education-training for university teaching	67	56	44
Mid-career education	66	100	100
Encourage splitting theses between two or more research groups	44	33	22
Establish a curriculum in technological forecasting and social impact evaluation	40	30	33

[1] Items were suggested by panelists in the first round, and presented in the second round.

Public Attitudes Toward Science and Technology

Public Attitudes Toward Science and Technology

■ Public attitudes affect science and technology in myriad ways. Public opinion sets the general climate—positive, neutral, or negative—for the development and use of scientific knowledge and technology. It influences the choice of ends to which the enterprise is directed, the magnitude and kinds of resources (economic, human, and institutional) allocated for research and innovation, and the selection by the young of careers in science and engineering.

To determine current public attitudes, a personal interview survey was conducted in May and June 1972 among 2,209 persons 18 years of age and more, using sampling techniques which permit the results to be projected to the total adult U.S. population.[1] The chances are 95 in 100 that the survey results do not vary by more than 2 percent (plus or minus) from the results that would be obtained if interviews had been conducted with all persons in this population.

The survey focused on three general aspects of the attitudes of the public: their regard for science and technology, their assessment of its impacts, and their expectations and desires for its future role in dealing with national problems.

The survey results are reported first for the total group, and subsequently for demographic subgroups. Since differences (ranging from 36 to 1 percent) in the frequency of "no opinion" occurred among the subgroups—and were particularly high for the oldest, lower income, lower education, and nonwhite groups—the results are reported for all those polled, as well as for all those expressing an opinion.

TOTAL GROUP RESPONSES

Public Regard for Science and Technology

This aspect of public opinion was explored from three different perspectives: the perceived effects of science and technology on the quality of life; the affective or emotional reaction to science and technology; and the standing or prestige of scientists and engineers in relationship to other occupations.

Science and technology have changed life for the "better" according to 70 percent of the public. Eleven percent felt that the changes were neither predominately good nor bad, while 8 percent felt that changes were for the "worse."

Do you Feel That Science and Technology Have Changed Life for the Better or for the Worse?

Response	*Percent*	*Percent of those having an opinion*
Better	70	77
Worse	8	9
Both	11	12
No effect	2	2
No opinion	9	—

To describe their emotional reaction to science and technology, the respondents expressed either "satisfaction or hope" (49 percent), "excitement or wonder" (23 percent), "fear or alarm" (6 percent), and "indifference or lack of interest" (6 percent).

Which One of These Items Best Describe Your General Reaction to Science and Technology?

Response	*Percent*	*Percent of those having an opinion*
Satisfaction or hope	49	58
Excitement or wonder	23	27
Fear or alarm	6	7
Indifference or lack of interest	6	7
No opinion	10	—

A further indication of the public regard for science and technology are the ratings of science and engineering as professions. From a list of nine professions, that of scientist was ranked second only to physicians, while engineers were grouped with ministers, lawyers, and architects. Comparison with previous surveys in 1947 and 1963 indicates a decline in ratings for all professions, although scientists maintained their relatively high position and engineers advanced in relative prestige.

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[1] The survey was conducted for this report by the Opinion Research Corporation, Princeton, N.J. A complete report of the study is available.

Choose the Statement That Best Gives Your Own Personal Opinion of the Prestige or General Standing That Each Job Has.

	1972 Ratings (percents)					*Total score*[1]		
Occupation	*Excellent*	*Good*	*Average*	*Below average*	*Poor*	*1972*	*1963*[2]	1947[2]
1. Physician	66	26	5	1		90	93	93
2. Scientist	59	27	8	1	1	86	92	89
3. Minister	44	36	15	2	1	83	87	87
4. Engineer	40	43	13	1		83	86	84
5. Lawyer	44	36	14	2	1	82	89	86
6. Architect	40	42	12	1		81	88	86
7. Banker	33	47	17	1		81	85	88
8. Accountant	29	46	19	1	1	78	81	81
9. Businessman	20	52	24	1	1	77	80	82

[1] Average of the ratings, where excellent = 100, good = 80, average = 60, below average = 40, and poor = 20.

[2] Scores from previous studies, which are comparable to present survey (see R. W. Hodge, P. M. Siegel, and P. H. Rossi, "Occupational Prestige in the United States, 1925-63," *American Journal of Sociology*, Volume LXX, No. 3, November 1964, pp 286-302.)

Impacts of Science and Technology

The public assessed several aspects of the impacts of science and technology—the net balance of beneficial and harmful consequences, the relative extent of the problems created, and the pace of change produced by science and technology—and appraised the adequacy of society's control over science and technology.

Fifty-four percent of those responding felt that science and technology do more good than harm, as compared with 31 percent who felt that the effects were about equally beneficial and harmful, and 4 percent who believed the impacts to be more harmful than good.

Overall, Would You Say That Science and Technology Do More Good Than Harm, More Harm Than Good, or About the Same Each?

Response	*Percent*	*Percent of those having an opinion*
More good	54	61
More harm	4	4
About the same	31	35
No opinion	11	

Those whose response was either that science and technology did "more good than harm" or "both good and harm" were asked to indicate "one of the good things." Similarly, those responding "more harm than good" were asked to identify "one of the harmful things." These results are summarized below.

Beneficial Contributions of Science and Technology (Cited by Group Responding "More Good than Harm")

Responses	*Percent*
Improvements in medicine/medical research	54
Space research/moon trip	12
Atomic research/nuclear science	5
Efforts to improve the environment	5
Development of TV, computers, etc.	3
Improved methods of transportation	3
Agriculture	2
Food research/processing	2
Don't know	4

Beneficial Contributions of Science and Technology (Cited by Group Responding "Both Good and Harm")

Responses	*Percent*
Improvements in medicine/medical research	50
Space research/moon trip	9
Efforts to improve the environment	5
Improved working/living conditions	5
Development of TV, computers, etc.	3
Improved methods of transportation	2
Food research/processing	2
Don't know	17

Harmful Activities of Science and Technology (Cited by Group Responding "More Harm than Good")

Responses	*Percent*
Lack of concern for the environment	27
Space program/moon trips	16
Development of weapons for war	9
Destruction of natural resources	2
Development of harmful medicines	2
Harmful drugs (development and publicity)	1
Don't know	23

Forty-eight percent of the public felt that "some" problems were caused by science and technology, as compared to 27 percent who believed that "few" problems were so caused, 9 percent who thought that "none" were produced, and 7 percent who believed that "most" problems were caused by science and technology.

Do You Feel That Science and Technology Have Caused Most of our Problems, Some of our Problems, Few of our Problems, or None of our Problems?

Response	*Percent*	*Percent of those having an opinion*
Most	7	8
Some	48	53
Few	27	30
None	9	10
No opinion	9	—

As for the pace of change, 51 percent of those responding felt that science and technology produced a desirable rate of change, whereas the remainder were divided as to whether the change was "too fast" (22 percent) or "too slow" (16 percent).

Do You Feel That Science and Technology Change Things Too Fast, Too Slowly, or Just About Right?

Response	*Percent*	*Percent of those having an opinion*
About right	51	57
Too fast	22	25
Too slowly	16	18
No opinion	11	—

Forty-eight percent of those responding felt that society's control over science and technology should "remain as it is," while 28 percent felt that control should be "increased," and 7 percent believed it should be "decreased."

Do You Feel That the Degree of Control That Society Has Over Science and Technology Should Be Increased, Decreased, or Remain as It Is Now?

Response	*Percent*	*Percent of those having an opinion*
Remain as it is	48	58
Increased	28	34
Decreased	7	8
No opinion	17	—

Expectations and Directions for Science and Technology

The public expressed confidence in the potential of science and technology to solve major problems. Forty-seven percent believed that it would eventually solve "some" problems, such as pollution, disease, drug abuse, and crime; 30 percent felt that it would solve "most"; 16 percent thought "few" would be solved.

Do You Feel That Science and Technology Will Eventually Solve Most Problems Such as Pollution, Disease, Drug Abuse, and Crime, Some of These Problems, or Few, if Any of These Problems?

Response	*Percent*	*Percent of those having an opinion*
Most problems	30	32
Some problems	47	51
Few problems	16	17
No opinion	7	—

The problem areas selected by the public in which they would most like (and least like) to have their taxes spent for science and technology are summarized in the following table.

In Which of the Areas Listed Would You Most Like (and Least Like) To Have Your Taxes Spent for Science and Technology?

	Percent choosing area¹	
Response	Most like	Least like
Improving health care	65	1
Reducing and controlling pollution	60	3
Reducing crime	59	2
Finding new methods for preventing and treating drug addiction	51	4
Improving Education	41	4
Improving the safety of automobiles	38	5
Developing faster and safer public transportation for travel within and between cities	23	14
Finding better birth control methods	20	18
Discovering new basic knowledge about man and nature	19	15
Weather control and prediction	11	19
Space exploration	11	42
Developing/improving weapons for national defense	11	30
No opinion	6	13

¹ Multiple responses accepted

Preferences are indicated for improving health care, controlling pollution, and reducing crime, whereas space exploration and development of defense weapons received least support. Mixed reactions were expressed for the areas of birth control, discovering new basic knowledge, and controlling and predicting weather.

On the whole, public attitudes toward science and technology appear to be positive. This is especially evident in their general regard for science and technology, and their confidence in its capacity to ameliorate national problems. Less positive opinions were expressed, however, regarding the impacts of science and technology, and the present uses to which it is put. On the whole, the public attitudes appear to reflect more confidence in the potential of science and technology than satisfaction with its present applications.

ANALYSIS OF RESULTS BY DEMOGRAPHIC SUBGROUPS

The response patterns of demographic subgroups, while similar, are not homogenous. A substantially greater frequency of "no opinion" responses is evident for the oldest, lowest income, least educated, and nonwhite subgroups. Such differences in "no opinion" response rates, while relevant, are not unique to this survey. In effect, they mask differences in expressed opinion toward science and technology. To avoid such ambiguities, comparisons of subgroup opinions are based on percentages of those expressing an opinion. These percentages and the frequency of "no opinion" among all subgroups are reported for selected questions in the following tables.

Overall, Would You Say That Science and Technology Do More Good Than Harm, More Harm Than Good, or About the Same of Each?

	Percentage of those expressing an opinion			Percentage of total Group expressing no opinion
Subgroups	More good	More harm	About same	
All	61	4	35	11
Men	64	4	32	8
Women	59	3	38	13
18-29 yrs.	55	5	39	8
30-39	69	2	29	7
40-49	66	5	29	7
50-59	60	4	35	9
60 +	57	4	39	19
< High school	51	6	43	18
High school	63	2	35	5
Some college	74	4	22	5
< $10,000	56	6	38	15
> $10,000	68	2	31	4
White	62	3	35	8
Nonwhite	54	11	35	28

For The Most Part, Do You Feel That Science and Technology Will Eventually Solve Most Problems Such as Pollution, Disease, Drug Abuse, and Crime, Some of These Problems, or Few if Any of These Problems?

	Percentage of those expressing an opinion			*Percentage of total group expressing*
Subgroups	*Most*	*Some*	*Few*	*No opinion*
All	32	51	17	7
Men	36	47	17	5
Women	29	54	18	9
18-29 yrs.	28	55	17	5
30-39	33	54	13	3
40-49	31	53	16	4
50-59	37	43	20	7
60 +	33	46	21	13
< High school	33	47	20	12
High school	29	55	16	4
Some college	35	51	14	3
< $10,000	31	49	19	10
> $10,000	33	52	15	2
White	33	51	17	5
Nonwhite	32	50	18	22

The intercorrelations among indicators of socioeconomic status (i.e., ethnicity, income, education) also make it difficult to relate variations to specific subgroups. Some general patterns, however, are evident. Among those expressing an opinion, respondents from relatively high socioeconomic groups indicate more positive attitudes about the contributions of science and technology than do respondents from relatively lower groups.

This socioeconomic difference appears to be overlayed with variation by age. Compared with other age groups, younger respondents (18-29 years of age) tend to be relatively negative about past contributions of science and technology, but relatively positive in their hopes for the future; middle-aged respondents tend to be relatively positive about both the past and the future; older respondents (over 60) are relatively negative about both the past and the future.

An additional variation appears among the responses of the sexes, as men tend to judge past contributions of science and technology more favorably, and express more optimism about its future.

Appendix A—Indicators

Table 1. R&D expenditures as a percent of gross national product, by country, 1963-71

[National currencies in billions]

Country	1963	1964	1967	1969	1970	1971
	R&D expenditures					
United States	17.4	19.2	23.6	26.2	26.7	27.3
France[1]	6.4	(2)	12.4	13.9	15.1	15.8
Germany	6.1	(2)	8.3	10.4	13.9	15.1
United Kingdom	0.73	0.77	0.94	1.02	1.08	1.14
Japan	321	(2)	606	933	1,200	1,500
U.S.S.R.	4.9	(2)	7.2	9.3	(2)	11.6
	Gross national product					
United States	590.5	632.4	793.9	929.1	974.1	1,047.0
France	396.0	(2)	573.2	725.6	815.2	903.0
Germany	377.6	(2)	495.5	603.4	682.1	750.6
United Kingdom	30.7	33.3	40.1	46.1	50.5	54.0
Japan	23,628	(2)	43,545	60,242	70,985	82,000
U.S.S.R.	206.8	(2)	282.0	329.6	362.6	386.6
	R&D expenditures as a percent of gross national product					
United States	2.94	3.04	2.97	2.81	2.73	2.60
France	1.62	(2)	2.16	1.92	1.85	1.75
Germany	1.62	(2)	1.68	1.72	2.04	2.01
United Kingdom	2.38	2.31	2.34	2.21	2.14	2.11
Japan	1.36	(2)	1.39	1.55	1.69	1.83
U.S.S.R.	2.37	(2)	2.55	2.82	(2)	3.00

[1] Gross expenditures for research and development.

[2] Not available.

Sources: Organisation for Economic Co-operation and Development, *International Survey of the Resources Devoted to R&D by OECD Member Countries* for 1963, 1967, and 1969; National Science Foundation estimates for 1970 and 1971; U.S.S.R. estimates for all years provided by Dr. Robert W. Campbell, Indiana University.

Table 2. Scientists and engineers[1] engaged in R&D per 10,000 population by country, 1963-71

Year	*United States*	*U.S.S.R.*	*France*	*Germany*	*Japan*
1963 ..	25	19	7	6[2]	12
1967 ..	27	26	10	11	16
1969 ..	28	32	11	12	17
1970 ..	27	([3])	12	14	21
1971 ..	25	37	12	15	25

[1] Full-time equivalents.

[2] 1964.

[3] Not available.

Sources: Organisation for Economic Co-operation and Development, *International Survey of the Resources Devoted to R&D by OECD Member Countries* for 1963, 1967, and 1969; National Science Foundation estimates for 1970 and 1971; U.S.S.R. estimates for all years provided by Dr. Robert W. Campbell, Indiana University.

Table 3. Distribution of government R&D expenditures among national objectives, by country, 1961 and 1969

National Objectives	*United States*	*United Kingdom*	*France*	*Germany*	*Japan*
Total (millions of dollars)	$11,089	$1.078	$601	$423	$235
			Percent distribution		
			1961		
National defense	65	65	40	22	4
Space	16	1	1	([1])	([1])
Community services	7	2	1	([1])	2
Economic development	4	11	8	([1])	30
Nuclear energy	7	15	29	16	7
Advancement of science	2	7	20	37	56
			1969		
National defense	49	40	31	19	2
Space	24	4	7	6	1
Community services	12	4	3	2	4
Economic development	7	26	16	2	23
Nuclear energy	6	12	18	17	8
Advancement of science	2	13	24	39	61

[1] Not available.

Source: Organisation of Economic Co-operation and Development, *Research and Development in OECD Member Countries: Trends and Objectives*, September 13, 1971.

Table 4. Scientific literature in selected fields as a percent of total literature produced by major developed nations, 1965-71

Selected field and year	*Total literature*	*United States*	*United Kingdom*	*Germany*	*France*	*U.S.S.R.*	*Japan*	*Other and unknown*
	Number	*Percent of total*						
Mathematics								
1965	2,971	23.9	6.6	6.3	5.6	22.4	4.2	31.8
1967	4,298	23.9	4.6	6.4	4.5	26.4	4.7	29.8
1969	3,024	26.9	6.4	6.0	6.9	20.0	5.2	27.1
1971	3,739	27.8	3.9	6.5	6.0	22.2	7.0	26.7
Physics and geophysics								
1965	23,224	41.3	8.2	7.4	4.8	15.7	4.4	18.2
1967	27,121	42.1	8.6	7.5	5.3	13.8	5.2	17.5
1969	29,353	41.0	8.3	7.2	5.4	14.6	5.1	18.4
1971	29,824	42.4	8.1	5.8	5.1	13.8	6.0	18.7
Chemistry and metallurgy								
1965	34,657	25.9	7.7	8.2	3.9	30.9	4.1	19.3
1967	39,730	24.5	7.9	8.4	5.9	28.8	5.3	19.2
1969	43,362	24.2	8.2	7.9	5.7	28.5	6.4	19.2
1971	45,052	23.9	8.4	6.8	6.2	29.0	5.9	19.8
Molecular biology								
1965	24,321	46.6	9.5	4.8	9.4	3.0	4.2	22.4
1967	25,858	48.6	11.0	5.4	7.4	2.1	4.8	20.7
1969	29,359	47.6	9.3	5.5	9.0	1.8	4.9	21.8
1971	30,148	48.7	8.9	5.1	8.9	1.8	5.0	21.6
Systematic biology								
1969	6,101	29.4	6.0	4.9	4.8	9.0	5.0	41.0
1971	7,050	33.3	7.2	5.3	5.2	6.4	4.3	38.2
Psychology								
1965	3,537	79.3	8.1	.5	.2	(1)	.5	11.4
1967	3,967	79.2	6.4	.5	.2	(1)	.6	13.2
1969	4,308	76.6	7.8	1.6	.1	(1)	.4	13.5
1971	4,075	76.5	7.9	.8	.2	(1)	.5	14.1
Engineering								
1965	10,006	49.9	11.2	4.7	1.4	12.6	2.4	17.8
1967	11,968	48.8	11.3	5.6	1.8	12.5	2.8	17.2
1969	13,222	48.3	11.0	6.2	1.8	12.5	2.9	17.4
1971	13,765	49.7	9.0	6.1	2.2	11.8	3.8	17.3
Economics								
1965	1,299	15.5	7.9	6.0	14.0	7.2	2.0	47.4
1967	1,314	16.5	8.1	6.0	14.[illegible]	7.3	3.7	44.4
1969	1,390	20.4	7.4	5.7	14.9	7.4	1.1	43.1
1971	1,138	22.9	6.3	6.1	11.9	4.8	.7	47.3

[1] Complete data not available for U.S.S.R.

Source: Computer Horizons, Inc., *Development of U.S. and International Indicators of the Quantity and Quality of Scientific Literature*, September 1972.

Table 5. Citation/publication ratio[1] of scientific literature in selected fields

Selected field	*United States*	*United Kingdom*	*Germany*	*France*	*U.S.S.R.*	*Japan*	*Other*
Physics and geophysics	1.25	1.23	.78	.48	.76	.64	.85
Chemistry and metallurgy	1.34	1.22	1.07	.63	.42	.63	.80
Molecular biology	1.28	1.14	.60	.37	.50	.67	.78
Systematic biology	.97	1.60	1.14	.85	(2)	.91	.80
Mathematics	1.10	1.42	.97	.66	.82	.84	.81
Engineering	1.19	1.03	.82	.63	.62	.84	.84
Psychology	1.05	.92	(2)	(2)	(2)	(2)	.84

[1] Average of 1965, 1967, 1969, and 1971.

[2] Not available.

Source: Computer Horisons, Inc., *Development of U.S. and International Indicators of the Quantity and Quality of Scientific Literature*, September 1972.

Table 6. Patents awarded to U.S. nationals by foreign countries[1] and to foreign nationals[1] by the United States, 1966-70

Patents awarded	*1966*	*1967*	*1968*	*1969*	*1970*
U.S. balance	23,061	21,798	23,226	17,026	14,286
Patents awarded to foreign nationals by the U.S.	9,282	9,662	8,928	11,817	11,961
Patents awarded to U.S. nationals by foreign countries	32,343	31,460	32,154	28,843	26,247

[1] United Kingdom, U.S.S.R., Germany, France, and Japan.

Source: World Intellectual Property Organization, *Industrial Property*. Geneva: 1967-71 (December issues).

Table 7. U.S. patent balance with selected countries, 1966-70

Selected country	*1966*	*1967*	*1968*	*1969*	*1970*
United Kingdom:					
Balance	11,440	10,877	10,107	9,503	9,776
Awarded to U.S.	14,117	13,676	12,588	——	12,728
Awarded by U.S.	2,677	2,799	2,481	——	2,952
France:					
Balance	8,371	9,353	9,348	5,135	3,932
Awarded to U.S.	9,807	10,911	10,794	6,943	5,664
Awarded by U.S.	1,436	1,558	1,446	1,808	1,732
Japan:					
Balance	3,561	2,008	3,439	2,505	2,149
Awarded to U.S.	4,683	3,432	4,903	4,657	4,774
Awarded by U.S.	1,122	1,424	1,464	2,152	2,625
Germany:					
Balance	—248	—362	362	—40	—1,552
Awarded to U.S.	3,733	3,406	3,804	4,483	2,882
Awarded by U.S.	3,981	3,766	3,442	4,523	4,434

Source: World Intellectual Property Organization, *Industrial Property*. Geneva: 1967-71 (December issues).

Table 8. Productivity in manufacturing industries, by country, 1960-71

[Index, 1960=100]

Year	*United States*	*Japan*	*France*	*Germany*	*United Kingdom*
1960 ..	100.0	100.0	100.0	100.0	100.0
1961 ..	102.4	113.3	104.6	105.9	100.5
1962 ..	108.1	118.1	109.3	112.2	103.0
1963 ..	112.6	127.8	114.7	118.2	109.0
1964 ..	117.9	144.7	120.7	127.3	116.1
1965 ..	122.6	150.2	127.4	136.1	120.2
1966 ..	124.1	166.0	136.2	141.7	124.1
1967 .	124.2	190.1	143.7	150.6	128.7
1968 ..	130.1	218.3	153.2	162.0	136.8
1969 ..	131.9	253.4	161.9	171.4	139.9
1970 ..	133.9	289.4	171.0	175.9	143.5
1971 ..	138.5	309.7	180.6	186.3	149.9

Source: Arthur Neef, "Unit Labor Costs in the U.S. and 10 Other Nations, 1960-71," *Monthly Labor Review*. Washington, D.C.: Bureau of Labor Statistics, Department of Labor, July 1972.

Table 9. Unit labor cost in manufacturing industries, by country, 1960-71

[Index, 1960=100]

Year	*United States*	*Japan*	*France*	*Germany*	*United Kingdom*
1960 ..	100.0	100.0	100.0	100.0	100.0
1961 ..	100.7	102.9	105.3	105.9	106.9
1962 ..	99.2	112.6	110.7	112.5	109.7
1963 ..	98.5	116.4	115.5	114.2	108.9
1964 ..	98.3	115.3	118.2	114.2	109.2
1965 ..	97.1	124.5	120.3	117.3	115.4
1966 ..	100.2	123.8	119.9	122.9	123.0
1967 ..	105.0	121.5	123.3	122.4	119.6
1968 ..	107.5	123.3	130.6	120.7	122.4
1969 ..	112.8	125.8	132.9	124.6	129.3
1970 ..	118.5	131.5	137.7	141.4	144.0
1971 ..	121.6	142.2	144.9	153.1	155.1

Source: Arthur Neef, "Unit Labor Costs in the U.S. and 10 Other Nations, 1960-71," *Monthly Labor Review*. Washington, D.C.: Bureau of Labor Statistics, Department of Labor, July 1972.

Table 10. U.S. payments and receipts for patents, manufacturing rights, licenses, etc., 1960-71

[Dollars in millions]

Year	*Receipts*	*Payments*	*Balance*
1960	$247	$ 40	$207
1961	244	46	198
1962	256	44	212
1963	273	51	222
1964	301	60	241
1965	335	67	268
1966	353	76	277
1967	398	105	293
1968	454	106	348
1969	501	120	381
1970	579	114	465
1971	621	126	495

Source: Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, June 1972.

Table 11. U.S. balance of payments for patents, manufacturing rights, licenses, etc., by country, 1960-71

[Dollars in millions]

Year	*Total*	*United Kingdom*	*Western Europe*[1]	*Japan*
1960				
Balance	$207	$31	$ 74	$ 48
Receipts	247	40	100	48
Payments	40	9	26	
1961				
Balance	198	31	59	52
Receipts	244	39	93	52
Payments	46	8	34	
1962				
Balance	212	31	64	51
Receipts	256	40	93	53
Payments	44	9	31	2
1963				
Balance	222	31	67	57
Receipts	273	43	102	58
Payments	51	12	34	1
1964				
Balance	241	33	74	65
Receipts	301	50	112	66
Payments	60	17	39	1
1965				
Balance	268	39	89	65
Receipts	335	57	132	66
Payments	67	18	43	1
1966				
Balance	277	32	87	67
Receipts	353	54	132	70
Payments	76	22	45	3
1967				
Balance	293	25	76	94
Receipts	398	56	136	97
Payments	104	32	62	4
1968				
Balance	348	21	86	129
Receipts	454	56	145	133
Payments	106	35	59	4
1969				
Balance	381	17	104	153
Receipts	501	58	170	157
Payments	120	41	66	4
1970				
Balance	465	23	128	198
Receipts	579	58	192	202
Payments	114	35	65	4
1971				
Balance	495	32	126	216
Receipts	621	67	200	221
Payments	126	35	74	5

[1] Except United Kingdom.

Source: Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, June 1972.

Table 12. U.S. trade balance in technology-intensive and nontechnology-intensive manufactured products, 1960-71

[Dollars in millions]

Product	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Technology intensive:												
Balance .	$5,850	$6,187	$6,672	$6,900	$ 7,887	$ 8,062	$ 7,885	$ 8,686	$ 9,624	$10,318	$11,570	$11,607
Export ...	7,517	7,928	8,617	8,864	10,137	10,948	12,015	13,227	15,104	16,732	19,024	19,958
Import ...	1,667	1,741	1,945	1,964	2,250	2,886	4,130	4,541	5,480	6,414	7,454	8,351
Nontechnology intensive:												
Balance .	—88	+137	—301	—411	—438	—1,221	—2,587	—3,434	—6,123	—7,201	—9,062	—11,070
Export ...	5,073	5,079	5,503	6,005	6,497	6,641	7,270	7,634	8,176	9,395	9,467	10,627
Import ...	5,161	4,942	5,804	6,416	6,935	7,862	9,857	11,068	14,299	16,595	18,529	21,697

Source: Department of Commerce, Bureau of International Commerce, *Overseas Business Reports* (OBR 67-43, August 1967 and OBR 72-005, April 1972).

Table 13a. U.S. trade balance in technology-intensive products, 1966-71

[Dollars in millions]

Product	1966	1967	1968	1969	1970	1971
Nonelectrical machinery:						
Balance	$3,972	$4,079	$4,126	$4,624	$5,343	$5,023
Export	5,637	6,032	6,400	7,241	8,435	8,516
Import	1,665	1,953	2,274	[illegible]	3,094	3,492
Aircraft:						
Balance	606	968	1,604	1,528	1,911	2,443
Export	878	1,216	1,887	1,812	2,185	2,741
Import	272	248	294	284	274	298
Chemicals:						
Balance	1,692	1,810	2,119	2,109	2,347	2,174
Export	2,602	2,706	3,177	3,255	3,677	3,673
Import	910	896	1,058	1,146	1,328	1,499
Electrical machinery:						
Balance	853	924	743	680	675	459
Export	1,863	2,059	2,234	2,620	2,934	3,006
Import	1,010	1,135	1,491	1,940	2,259	2,547
Instruments:						
Balance	331	369	379	421	469	471
Export	544	604	640	754	824	850
Import	213	235	261	333	355	379

Source: Department of Commerce, Bureau of International Commerce, *Overseas Business Reports* (OBR 72-005, April 1972).

Table 13b. U.S. trade balance with other nations in technology-intensive products,[1] 1966-71

[Dollars in millions]

Nations	*1966*	*1967*	*1968*	*1969*	*1970*	*1971*
Developing nations:						
Balance	$3,659	$3,916	$4,544	$4,595	$5,102	$5,313
Export	3,902	4,162	4,877	5,079	5,731	6,119
Import	243	246	333	484	629	806
Western Europe:						
Balance	1,666	1,861	1,897	2,310	3,162	2,697
Export	3,641	3,937	4,351	4,979	6,147	5,919
Import	1,975	2,076	2,454	2,669	2,985	3,222
Canada:						
Balance	1,777	1,691	1,552	1,812	1,559	1,854
Export	2,815	2,914	2,975	3,376	3,388	3,903
Import	1,038	1,223	1,423	1,564	1,829	2,049
Japan:						
Balance	—147	—133	—221	—353	—253	—552
Export	647	754	909	1,151	1,507	1,484
Import	794	887	1,130	1,504	1,760	2,036

[1] Excludes military aircraft.

Source: Department of Commerce, Bureau of International Commerce, *Overseas Business Reports* (OBR 72-001, May 1972).

Table 14a. National R&D expenditures, 1961-72

[Dollars in billions]

Year	*Current dollars*	*Constant 1958 dollars*[1]
1961	$14.6	$13.9
1962	15.7	14.8
1963	17.4	16.2
1964	19.2	17.7
1965	20.4	18.4
1966	22.3	19.5
1967	23.6	20.1
1968	25.1	20.5
1969	26.2	20.4
1970	26.7	19.7
1971 (prelim.)	27.3	19.3
1972 (est.)	28.9	19.8

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 14b. National R&D expenditures as a percent of gross national product, by sector, 1961-72
[Dollars in billions]

Year	Total R&D expenditures	GNP	Total R&D as percent of GNP	Federal		Industry		Other	
				Amount	Percent of GNP	Amount	Percent of GNP	Amount	Percent of GNP
1961	$14.55	$ 520.1	2.80	$ 9.264	1.781	$ 4.749	0.913	$ .539	.104
1962	15.67	560.3	2.80	9.926	1.772	5.114	.913	.625	.112
1963	17.37	590.5	2.94	11.219	1.900	5.449	.923	.703	.119
1964	19.21	632.4	3.04	12.553	1.985	5.880	.930	.781	.124
1965	20.44	684.9	2.98	13.033	1.903	6.539	.955	.867	.127
1966	22.27	749.9	2.97	13.992	1.866	7.317	.976	.957	.128
1967	23.61	793.9	2.97	14.419	1.816	8.134	1.025	1.059	.133
1968	25.12	864.2	2.91	14.952	1.730	8.997	1.041	1.170	.135
1969	26.18	930.3	2.81	14.914	1.603	10.008	1.076	1.254	.135
1970	26.70	976.4	2.73	14.798	1.516	10.541	1.080	1.356	.139
1971	27.32	1,050.4	2.60	14.991	1.427	10.911	1.039	1.418	.135
1972 (est.)	28.94	1,150.5	2.52	15.900	1.382	11.570	1.006	1.470	.128

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 14c. National R&D expenditures, by source, 1961-72
[Dollars in billions]

Year	Current dollars			Constant 1958 dollars[1]		
	Federal Government	Industry	Universities and colleges	Federal Government	Industry	Universities and colleges
1961	$ 9.3	$ 4.7	$ .4	$ 8.9	$4.5	$ .4
1962	9.9	5.1	.4	9.4	4.8	.4
1963	11.2	5.4	.5	10.5	5.1	.5
1964	12.6	5.9	.6	11.5	5.4	.5
1965	13.0	6.5	.6	11.8	5.9	.6
1966	14.0	7.3	.7	12.3	6.4	.6
1967	14.4	8.1	.8	12.3	6.9	.6
1968	15.0	9.0	.8	12.2	7.4	.7
1969	14.9	10.0	.9	11.6	7.8	.7
1970	14.8	10.5	1.0	10.9	7.8	.7
1971 (prelim.)	15.0	10.9	1.0	10.6	7.7	.7
1972 (est.)	15.9	11.6	1.1	10.9	7.9	.7

[1] GNP price deflator was used to convert current to constant dollars.

Note: Other nonprofit institutions' R&D expenditures ranged from $110 million in 1961 to $235 million in 1972.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 14d. National R&D expenditures, by character of work, 1961-72

[Dollars in billions]

Year	Current dollars			Constant 1958 dollars[1]		
	Basic research	Applied research	Development	Basic research	Applied research	Development
1961	1.5	1.5	3.2	3.0	9.9	9.4
1962	1.9	1.8	3.8	3.6	10.0	9.5
1963	2.2	2.0	3.9	3.6	11.3	10.5
1964	2.6	2.4	4.3	4.0	12.4	11.4
1965	2.9	2.6	4.5	4.1	13.0	11.8
1966	3.1	2.7	4.8	4.2	14.3	12.6
1967	3.4	2.9	5.0	4.3	15.2	12.9
1968	3.7	3.0	5.4	4.4	16.0	13.1
1969	3.8	2.9	5.6	4.4	16.8	13.1
1970	3.9	2.9	6.0	4.4	16.8	12.4
1971 (prelim.)	3.9	2.8	6.1	4.3	17.3	12.2
1972 (est.)	4.1	2.8	6.5	4.4	18.4	12.5

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 15. Scientists and engineers[1] employed in R&D, by sector, 1961-72

[In thousands]

Year	Total	Federal Government	Industry	Universities and colleges	Other
1961	425.2	50.6	312.0	42.4	20.2
1965	496.2	64.2	348.4	53.4	30.5
1968	550.6	68.3	381.9	66.0	34.4
1969	559.4	70.3	385.8	68.3	35.0
1970	549.7	69.8	377.4	68.5	34.0
1971	532.8	68.5	363.4	68.4	32.5
1972 (est.)	525.4	68.0	356.0	67.6	33.8

Full-time equivalents.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 16. Federal R&D expenditures as a percent of total Federal outlays, fiscal years 1961-72

[Dollars in millions]

Fiscal Year	Total Federal outlays	Fed'l expenditures for R&D	Percent
1961	92,136	8,747.9	9.5
1962	101,005	9,831.6	9.7
1963	104,740	11,338.5	10.8
1964	111,651	13,758.9	12.3
1965	111,182	13,811.4	12.4
1966	126,731	14,970.2	11.8
1967	149,602	16,073.0	10.7
1968	169,588	16,333.3	9.6
1969	173,874	15,695.4	9.0
1970	184,656	15,159.3	8.2
1971	199,192	15,300.1	7.7
1972 (est.) ...	221,620	16,007.4	7.2

Source: National Science Foundation, *An Analysis of Federal R&D Funding by Budget Fuction, 1960-1972* (NSF 71-25) and *An Analysis of Federal R&D Funding by Function, Fiscal Years 1963-1973* (NSF 72-313).

Table 17. Federal R&D expenditures for selected functions, fiscal years 1963-72

[Dollars in millions]

Function	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
					Current dollars					
National defense	7,273.3	7,999.8	7,179.3	7,199.9	8,133.7	8,592.8	8,321.7	8,067.1	8,161.7	8,702.7
Space	2,429.7	3,832.0	4,638.3	5,409.1	5,168.0	4,576.7	4,119.6	3,596.7	3,207.5	2,960.1
Health	593.8	740.5	662.8	798.5	921.8	1,125.3	1,093.7	1,164.1	1,217.3	1,386.8
Advancement of science and technology	296.4	356.4	371.7	423.4	493.6	544.5	571.4	589.9	619.3	704.6
Environment	171.9	189.7	213.1	235.1	275.2	304.1	331.8	370.4	419.6	509.2
Transportation	112.0	145.9	198.3	264.7	356.2	365.9	377.9	451.0	684.1	607.3
Energy conversion and development	265.3	278.6	281.2	274.6	293.5	344.7	345.6	341.0	336.9	405.2
Agriculture	138.8	150.4	169.0	195.8	214.8	225.9	228.6	239.1	261.8	288.1
Economic security	22.1	27.0	41.6	94.4	86.7	97.5	133.9	144.1	149.1	153.9
Education	9.6	12.7	19.4	37.5	70.0	86.8	93.4	93.7	115.0	125.5
					Constant 1958 dollars[1]					
National defense	6,835.8	7,414.1	6,532.6	6,422.7	7,030.0	7,172.6	6,657.4	6,120.7	5,888.7	6,051.9
Space	2,283.6	3,551.4	4,220.5	4,825.2	4,466.7	3,820.3	3,295.7	2,729.0	2,314.2	2,058.5
Health	558.1	686.3	603.1	712.3	796.7	939.3	875.0	883.2	878.2	964.4
Advancement of science and technology	278.6	330.3	338.2	377.7	426.6	454.5	457.1	447.6	446.8	490.0
Environment	161.6	175.8	193.9	209.7	237.9	253.8	265.4	281.0	302.7	354.1
Transportation	105.3	135.2	180.4	236.1	307.9	305.4	302.3	342.2	493.6	422.3
Energy conversion and development	249.3	258.2	255.9	245.0	253.7	287.7	276.5	258.7	243.1	281.8
Agriculture	130.5	139.4	153.8	174.7	185.7	188.6	182.9	181.4	188.9	200.3
Economic security	20.8	25.0	37.9	84.2	74.9	81.4	107.1	109.3	107.6	107.0
Education	9.0	11.8	17.7	33.5	60.5	72.5	74.7	71.1	83.0	87.3

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *An Analysis of Federal R&D Funding by Function, Fiscal Years 1963-73* (NSF 72-313)

Table 18a. Industrial R&D expenditures, 1961-72
[Dollars in billions]

Year	Current dollars	Constant 1958 dollars[1]
1961	$10.9	$10.4
1962	11.5	10.8
1963	12.6	11.8
1964	13.5	12.4
1965	14.2	12.8
1966	15.5	13.6
1967	16.4	13.9
1968	17.4	14.3
1969	18.3	14.3
1970	18.2	13.4
1971	18.4	13.0
1972 (est.)	19.5	13.4

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 18b. Industrial R&D expenditures, by source, 1961-72
[Dollars in billions]

Year	Current dollars		Constant 1958 dollars[1]	
	Industry	Federal Government	Industry	Federal Government
1961	$4.7	$6.2	$4.5	$6.0
1962	5.0	6.4	4.8	6.1
1963	5.4	7.3	5.0	6.8
1964	5.8	7.7	5.3	7.1
1965	6.4	7.7	5.8	7.0
1966	7.2	8.3	6.3	7.3
1967	8.0	8.4	6.8	7.1
1968	8.9	8.6	7.3	7.0
1969	9.9	8.5	7.7	6.6
1970	10.4	7.8	7.7	5.8
1971	10.7	7.8	7.6	5.4
1972 (est.)	11.4	8.1	7.8	5.6

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 19. Scientists and engineers[1] engaged in industrial R&D, by source of funds, 1962-71

Year	Industry	Federal Government
January 1962	172,800	139,200
January 1963	169,500	157,800
January 1964	174,600	165,600
January 1965	180,400	163,200
January 1966	190,300	162,900
January 1967	205,700	161,300
January 1968	219,600	156,800
January 1969	229,500	157,700
January 1970	235,900	148,200
January 1971	229,700	129,600

[1] Full-time equivalents.

Source: National Science Foundation, *Research and Development in Industry, 1970* (NSF 72-309).

Table 20. Industry's own funds for R&D, by selected industry, 1961-70

[Dollars in millions]

Industry	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*1967*	*1968*	*1969*	*1970*
					Current dollars					
Electrical equipment and communication ...	$887	$949	$1,017	$1,093	$1,206	$1,414	$1,552	$1,753	$1,965	$2,061
Chemicals and allied products	881	939	1,004	1,098	1,198	1,271	1,357	1,458	1,538	1,624
Machinery	588	644	709	788	860	974	1,066	1,197	1,355	1,445
Motor vehicles and other transportation equipment	711	718	799	854	898	995	986	1,106	1,257	1,232
Aircraft and missiles	392	454	452	445	622	753	1,070	1,152	1,276	1,107
Petroleum refining and extraction	280	289	296	338	364	383	409	468	522	565
Professional and scientific instruments	180	202	202	229	257	298	321	388	455	508
					Constant 1958 dollars[1]					
Electrical equipment and communication ...	848	897	949	1,004	1,088	1,241	1,320	1,433	1,533	1,524
Chemicals and allied products	842	888	937	1,009	1,081	1,116	1,115	1,192	1,200	1,201
Machinery	562	609	662	724	776	855	907	979	1,057	1,069
Motor vehicles and other transportation equipment	680	679	746	785	810	873	839	904	981	911
Aircraft and missiles	375	429	422	409	561	661	910	942	995	819
Petroleum refining and extraction	268	273	276	311	328	336	348	383	407	418
Professional and scientific instruments	172	191	189	210	232	262	273	317	355	376

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *Research and Development in Industry, 1970* (NSF 72-309).

Table 21a. Basic research expenditures, by performer, 1960-72

[Dollars in millions]

Year	Total	Universities and colleges	Government	Industry	FFRDC's[1]	Nonprofit institutions
			Current dollars			
1960	$1,326	$576	$160	$376	$ 97	$117
1961	1,543	701	206	395	115	126
1962	1,886	850	251	488	136	161
1963	2,196	1,036	299	522	159	180
1964	2,559	1,261	364	549	191	194
1965	2,853	1,419	424	592	208	210
1966	3,127	1,601	449	624	227	226
1967	3,362	1,785	478	629	250	221
1968	3,658	2,011	512	642	276	217
1969	3,770	2,087	577	618	275	213
1970	3,946	2,185	658	629	269	205
1971 (prelim.) ...	3,926	2,281	535	625	260	225
1972 (est.)	4,100	2,335	575	660	285	245
			Constant 1958 dollars[2]			
1960	1,284	558	155	364	94	113
1961	1,475	670	197	377	110	120
1962	1,783	804	237	461	129	152
1963	2,049	967	279	487	148	168
1964	2,351	1,159	334	504	176	178
1965	2,573	1,280	382	534	188	189
1966	2,744	1,405	394	548	199	198
1967	2,860	1,518	406	535	213	188
1968	2,991	1,644	419	525	226	177
1969	2,941	1,628	450	482	214	166
1970	2,918	1,616	486	465	199	152
1971 (prelim.) ...	2,772	1,611	378	441	184	159
1972 (est.)	2,812	1,602	394	453	195	168

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[1] Federally Funded Research and Development Centers administered by universities.

[2] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 21b. Sources of funds for basic research, 1960-72

[Dollars in millions]

Year	Total	Federal Government	Industry	Universities and colleges	Nonprofit institutions
			Current dollars		
1960	$1,326	$ 693	$331	$215	$ 87
1961	1,543	841	350	250	102
1962	1,886	1,091	382	293	120
1963	2,196	1,310	414	343	129
1964	2,559	1,595	424	402	138
1965	2,853	1,817	448	445	143
1966	3,127	1,990	496	494	147
1967	3,363	2,179	477	551	156
1968	3,658	2,354	518	621	165
1969	3,770	2,398	519	678	175
1970	3,946	2,474	535	747	196
1971 (prelim.)	3,926	2,416	520	793	197
1972 (est.)	4,100	2,525	545	825	205
			Constant 1958 dollars[1]		
1960	1,284	671	320	208	84
1961	1,475	803	334	239	97
1962	1,783	1,031	361	277	113
1963	2,049	1,222	386	320	120
1964	2,351	1,465	389	369	127
1965	2,573	1,639	404	401	129
1966	2,744	1,746	435	433	129
1967	2,860	1,853	406	468	133
1968	2,991	1,925	423	508	135
1969	2,941	1,870	405	529	136
1970	2,918	1,829	396	552	140
1971 (prelim.)	2,772	1,706	367	560	139
1972 (est.)	2,812	1,732	374	566	141

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[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 22. Federal expenditures for basic research, by performer, 1960-72

[Dollars in millions]

Year	Federal intramural	Industry	Universities and colleges	FFRDC's[1]	Nonprofit institutions
			Current dollars		
1960	160	79	299	97	58
1961	206	81	382	115	57
1962	251	143	481	136	80
1963	299	147	610	159	95
1964	364	165	767	191	108
1965	424	186	879	208	120
1966	449	173	1,009	227	132
1967	478	202	1,124	250	125
1968	512	180	1,268	276	118
1969	577	160	1,275	275	111
1970	658	159	1,288	269	100
1971 (prelim.)	535	170	1,336	260	115
1972 (est.)	575	180	1,355	285	130
			Constant 1958 dollars[2]		
1960	155	76	290	94	56
1961	197	77	365	110	54
1962	237	135	455	128	76
1963	279	137	569	148	89
1964	334	151	705	175	99
1965	382	168	793	188	108
1966	394	152	885	199	116
1967	406	172	956	213	106
1968	419	147	1,037	226	96
1969	450	125	994	214	86
1970	486	117	952	199	74
1971 (prelim.)	378	120	943	184	81
1972 (est.)	394	123	929	195	89

[1] Federally Funded Research and Development Centers administered by universities.

[2] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303)

Table 23. Federal obligations for basic research, by supporting agency, 1960-72

[Dollars in millions]

Agency	*1960*	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*1967*	*1968*	*1969*	*1970*	*1971*	*1972 (est.)*
							Current dollars						
Total	$610	$825	$1,106	$1,389	$1,567	$1,600	$1,844	$2,015	$2,072	$2,094	$2,062	$2,132	$2,395
Department of Agriculture	34	41	50	56	68	90	94	100	100	107	116	118	138
Department of Defense	168	173	204	231	241	263	262	284	263	276	247	262	265
Department of Health, Education, and Welfare	103	137	190	236	274	303	326	372	397	371	388	397	467
Atomic Energy Commission	104	167	192	219	238	258	281	302	282	285	287	277	270
National Aeronautics and Space Administration	97	190	316	447	524	528	559	603	656	678	637	680	750
National Science Foundation	68	77	104	141	155	171	223	239	252	248	245	273	353
All others	35	39	50	59	66	77	98	115	122	129	142	125	152
							Constant 1958 dollars[1]						
Total	591	789	1,046	1,296	1,440	1,524	1,618	1,714	1,694	1,633	1,525	1,506	1,643
Department of Agriculture	33	39	47	52	62	81	82	85	82	83	86	83	95
Department of Defense	163	165	193	216	221	237	230	242	215	215	183	185	182
Department of Health, Education, and Welfare	100	131	180	220	252	273	286	316	325	289	287	280	320
Atomic Energy Commission	101	160	182	204	219	233	203	257	231	222	212	196	185
National Aeronautics and Space Administration	94	182	299	417	481	476	491	513	536	529	471	480	514
National Science Foundation	66	74	98	132	142	154	196	203	206	193	181	193	242
All others	34	37	47	55	61	69	86	98	100	101	105	88	104

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

Table 24. Estimated expenditures for basic research in universities and colleges, by field of science, 1964-72
[Dollars in millions]

Field of science	*1964*	*1966*	*1968*	*1970*	*Prel. est.* *1972*
			Current dollars		
Total	$1,261	$1,601	$2,011	$2,186	$2,541
Engineering	162	226	270	280	309
Physical sciences	212	270	296	300	329
Astronomy	15	20	22	16	22
Chemistry	72	82	96	97	112
Physics	111	151	160	156	163
Physical sciences, n.e.c	13	17	17	31	32
Environmental sciences	52	62	109	105	138
Mathematics	39	46	63	82	79
Life sciences	643	784	940	1,058	1,228
Biological sciences	287	367	433	450	580
Clinical medical	311	360	443	497	571
Life sciences, n.e.c.	45	58	64	111	77
Psychology	36	44	62	64	88
Social sciences	98	131	195	217	275
Other sciences, n.e.c.	18	36	77	80	95
			Constant 1961 dollars[1]		
Total	1,159	1,378	1,584	1,555	1,626
Engineering	149	194	212	199	198
Physical sciences	195	233	233	213	210
Astronomy	14	17	18	11	14
Chemistry	67	71	76	69	72
Physics	102	130	126	111	104
Physical sciences, n.e.c.	12	15	14	22	20
Environmental sciences	48	53	86	75	88
Mathematics	36	41	50	58	51
Life sciences	591	675	740	752	786
Biological sciences	264	316	341	320	371
Clinical medical	286	310	349	354	365
Life sciences, n.e.c.	41	49	50	78	49
Psychology	33	38	49	46	56
Social sciences	90	112	154	154	176
Other sciences, n.e.c.	17	31	61	57	61

[1] Academic R&D price deflator.

Note: Detail may not add to totals because of rounding.

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges, 1971* (NSF 72-315).

Table 25. Estimated Federal expenditures for basic research in universities and colleges, by field of science, 1964-72

[Dollars in millions]

Field of science	*1964*	*1966*	*1968*	*1970*	*Prel. est. 1972*
			Current dollars		
Total	766	1,009	1,251	1,289	1,409
Engineering	105	151	181	182	196
Physical sciences	164	209	223	237	233
Astronomy	13	17	18	14	15
Chemistry	50	60	70	71	73
Physics	95	122	132	132	124
Physical sciences, n.e.c.	6	10	13	21	21
Environmental sciences	39	47	71	72	95
Mathematical and computer sciences	21	26	34	43	41
Life sciences	371	472	584	591	649
Biological sciences	126	160	204	200	245
Clinical medical	218	279	345	348	372
Life sciences, n.e.c.	27	33	35	43	32
Psychology	24	30	39	40	52
Social sciences	37	53	82	83	90
Other sciences, n.e.c.	5	21	37	41	53
			Constant 1961 dollars[1]		
Total	704	868	985	917	901
Engineering	96	130	142	129	125
Physical sciences	151	180	176	169	149
Astronomy	12	15	14	10	10
Chemistry	46	52	55	50	47
Physics	87	105	104	94	79
Physical sciences, n.e.c.	6	9	10	15	13
Environmental sciences	36	40	56	51	61
Mathematical and computer sciences	19	22	27	31	26
Life sciences	341	406	460	420	415
Biological sciences	116	138	161	142	157
Clinical medical	200	240	272	247	238
Life sciences, n.e.c.	25	28	27	31	20
Psychology	22	26	31	28	33
Social sciences	34	46	65	59	58
Other sciences, n.e.c.	5	18	29	29	34

[1] Academic R&D price deflator.

Note: Detail may not add to totals because of rounding.

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges, 1971* (NSF 72-315).

Table 26. Federal and non-Federal research funds per scientist and engineer in doctorate-granting institutions,[1] 1964-72

Year	Research expenditures (constant 1961 dollars[2]) Total	Federal	Non-Federal	Number of scientists and engineers
1964	$13,138	$7,673	$5,465	103,587
1966	13,159	8,040	5,119	125,488
1968	13,484	8,239	5,245	140,163
1970	11,826	6,906	4,920	157,276
1972-est ..	11,424	6,272	5,152	170,000

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[1] Includes all scientists and engineers (full-time-equivalent basis) employed in universities

[2] Academic R&D price deflator

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges, 1971*, (NSF 72-315).

Table 27. Research expenditures per scientist and engineer[1] in doctorate-granting institutions, by selected field of science, 1964-72

Field of science	1964	1966	1968	1970	1972
	Research expenditures per scientist or engineer				
Biological sciences	$22,107	$24,066	$24,140	$20,594	$22,636
Physics	24,483	24,722	23,499	19,580	16,073
Engineering	12,728	13,845	15,457	13,405	12,359
Chemistry	14,448	13,200	12,810	11,298	11,272
Psychology	10,425	9,758	9,356	8,174	9,299
Clinical medicine	12,049	11,449	10,676	9,358	8,462
Social sciences	7,718	7,332	8,201	7,490	7,847
Mathematics and computer sciences	7,268	6,966	6,656	7,110	5,630
	Total research expenditures (In millions of constant 1961 dollars[2])				
Biological sciences	$339.2	$396.2	$415.5	$387.3	$455.0
Physics	113.7	151.4	148.4	131.5	109.7
Engineering	174.5	231.9	254.5	239.3	237.9
Chemistry	76.2	81.0	86.0	78.7	80.6
Psychology	35.5	41.6	53.2	50.7	63.7
Clinical medicine	318.6	388.1	427.1	434.1	426.5
Social sciences	105.1	130.2	176.9	177.4	200.1
Mathematics and computer sciences	39.3	47.0	56.3	66.9	56.3
	Number of scientists and engineers				
Biological sciences	15,343	16,467	17,212	18,809	20,100
Physics	4,644	6,124	6,315	6,718	6,825
Engineering	13,709	16,749	16,465	17,849	18,500
Chemistry	5,274	6,134	6,713	6,969	7,150
Psychology	3,405	4,263	5,686	6,208	6,850
Clinical medicine	26,442	33,897	40,003	46,381	50,400
Social sciences	13,616	17,756	21,569	23,683	25,500
Mathematics and computer sciences	5,407	6,747	8,458	9,417	10,000

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[1] Includes all scientists and engineers (full-time-equivalent basis) employed in universities.

[2] Academic R&D price deflator.

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges, 1971* (NSF 72-315) and Survey of Scientific Activities of Institutions of Higher Education, 1973.

Table 28. Proportion of Ph.D. academic staff in science receiving Federal support and engaged in basic research, by field, 1964-70

[Percent]

Field of science	*1964*	*1966*	*1968*	*1970*
All fields	69	69	64	57
Physics	84	82	78	74
Biology	77	78	76	71
Chemistry	74	74	66	60
Psychology	67	66	62	53
Earth and marine sciences	54	56	54	51
Mathematics	51	47	43	30
Social sciences	36	39	37	30

Source: National Science Foundation, special tabulations from the National Register of Scientific and Technical Personnel, 1964-70.

Table 29. Proportion of young and senior Ph.D. academic staff in science receiving Federal support and engaged in basic research, 1964-70

[Percent]

Academic staff	*1964*	*1966*	*1968*	*1970*
Senior	73	74	69	63
Junior	64	63	58	50

Source: National Science Foundation, special tabulations from the National Register of Scientific and Technical Personnel, 1964-70.

Table 31. Total Federal expenditures for intramural basic research, 1960-72

[Dollars in millions]

Year	*Current dollars*	*Constant 1958 dollars*[1]
1960	$160	$155
1961	206	197
1962	251	237
1963	299	279
1964	364	334
1965	424	382
1966	449	394
1967	478	406
1968	512	419
1969	577	450
1970	658	486
1971 (prelim.)	535	378
1972 (est.)	575	394

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 30. Ratio of young to senior Ph.D. academic staff receiving Federal support and engaged in basic research, by field, 1964-70

Field of science	*Percent of senior*				*Ratio of young to senior*			
	1964	*1966*	*1968*	*1970*	*1964*	*1966*	*1968*	*1970*
Physics	86	86	83	78	95	90	89	86
Chemistry	77	78	70	63	93	91	90	90
Social sciences	37	43	39	34	93	81	87	74
Psychology	70	71	70	62	89	84	80	72
Biology	81	81	80	74	87	90	89	87
Earth and marine sciences	54	56	53	51	81	87	86	91
Mathematics	60	59	56	45	70	64	60	48

Source: National Science Foundation, special tabulations from the National Register of Scientific and Technical Personnel, 1964-70.

Table 32. Federal obligations for intramural basic research, by selected agency, 1960-72

[Dollars in millions]

Agency	*1960*	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*1967*	*1968*	*1969*	*1970*	*1971*	*1972*
	Current dollars												
Department of Defense	$52.9	$54.5	$65.1	$72.8	$75.7	$80.0	$84.8	$81.9	$86.2	$90.3	$95.6	$99.0	$106.9
National Aeronautics and Space Administration	27.1	48.7	63.2	83.9	127.0	158.2	154.7	163.1	179.3	202.4	238.7	171.5	168.1
Department of Agriculture ..	22.9	28.1	31.7	36.7	42.5	57.0	62.4	63.3	67.3	76.6	85.4	86.5	97.2
Department of Health, Education, and Welfare	17.8	24.9	30.6	38.9	44.6	47.0	58.6	66.7	69.6	88.3	113.7	67.5	76.7
Department of the Interior	18.7	21.4	22.7	23.9	26.2	30.5	33.7	39.6	41.3	42.9	39.8	41.2	48.0
Department of Commerce ..	8.6	10.7	15.0	18.7	20.6	21.8	19.9	21.7	23.6	26.4	35.9	35.3	41.8
	Constant 1958 dollars[1]												
Department of Defense	52.0	52.8	62.2	68.8	69.6	72.2	74.4	69.6	70.5	70.4	70.7	69.9	73.3
National Aeronautics and Space Administration	26.7	47.1	60.4	79.3	116.7	142.7	135.8	138.7	146.6	157.9	176.5	121.1	115.3
Department of Agriculture ..	22.5	27.2	30.3	34.7	39.1	51.4	54.8	62.3	55.0	59.8	63.2	61.1	66.7
Department of Health, Education, and Welfare	17.5	24.1	29.2	36.8	41.0	42.3	51.4	56.7	56.9	68.9	84.1	47.7	52.6
Department of the Interior	18.4	20.7	21.7	22.6	24.1	27.5	29.6	33.7	33.8	33.5	29.4	29.1	32.9
Department of Commerce ..	8.5	10.4	14.3	17.7	18.9	19.7	17.5	18.5	19.3	20.6	26.5	24.9	28.7

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

Table 33. Industrial basic research expenditures, by source, 1960-72

[Dollars in millions]

	Total		*Industry*		*Federal Government*	
Year	*Current dollars*	*Constant 1958 dollars[1]*	*Current dollars*	*Constant 1958 dollars[1]*	*Current dollars*	*Constant 1958 dollars[1]*
1960	$376	$364	$297	$287	$ 79	$ 76
1961	395	377	314	300	81	77
1962	488	461	345	326	143	135
1963	522	487	375	350	147	137
1964	549	504	384	353	165	152
1965	592	534	406	366	186	168
1966	624	548	451	396	173	152
1967	629	535	427	363	202	172
1968	642	525	462	378	180	147
1969	618	482	458	357	160	125
1970	629	465	470	347	159	117
1971 (prelim.) ...	625	441	455	321	170	120
1972 (est.)	660	453	480	329	180	123

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303).

Table 34. Industrial basic research expenditures, by field of science, 1967-70

[Dollars in millions]

Field of science	*1967*	*1968*	*1969*	*1970*
	Current dollars			
Engineering	172	181	171	174
Chemistry	162	191	213	200
Physics and astronomy	146	126	110	97
Life sciences	69	76	74	80
Mathematics	12	14	13	14
Environmental sciences	14	11	12	8
	Constant 1958 dollars[1]			
Engineering	146	148	133	129
Chemistry	138	156	166	148
Physics and astronomy	124	103	86	72
Life sciences	59	62	58	59
Mathematics	10	11	10	10
Environmental sciences	12	9	9	6

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *Research and Development in Industry, 1970* (NSF 72-309).

Table 36. Natural scientists and engineers in relation to total civilian employment,[1] 1950-70

Year	*Scientists and engineers (in thousands)*	*Total civilian employment (in thousands)*	*Scientists and engineers per 10,000 civilian employees*
1950	556.7	58,920	94
1951	611.8	59,962	102
1952	685.9	60,254	114
1953	748.7	61,181	122
1954	783.7	60,110	130
1955	812.6	62,171	131
1956	873.7	63,802	137
1957	958.9	64,071	150
1958	1,001.2	63,036	159
1959	1,057.9	64,630	164
1960	1,104.0	65,778	168
1961	1,151.5	65,746	175
1962	1,210.3	66,702	181
1963	1,280.8	67,762	189
1964	1,327.0	69,305	191
1965	1,366.9	71,088	192
1966	1,417.5	72,895	194
1967	1,476.7	74,372	199
1968	1,525.0	75,920	201
1969	1,567.7	77,902	201
1970	1,594.7	78,627	203

[1] 16 years of age or over.

Source: Estimates prepared by the National Science Foundation based on data collected by the Foundation and the Bureau of Labor Statistics, Department of Labor.

Table 35. Total scientists and engineers, by broad field, 1960 and 1970

Field	*Total* 1960	*Total* 1970	*Ph.D.'s* 1960	*Ph.D.'s* 1970
Total	1,167,000	1,731,000	89,200	171,800
Engineers	797,000	1,100,000	7,500	25,700
Physical scientists	168,000	253,000	30,400	55,000
Life scientists	98,000	180,000	24,700	42,000
Social scientists	70,000	126,000	22,600	38,400
Mathematicians	34,000	76,000	4,000	10,700

Source: Estimates prepared by the National Science Foundation based on data collected by the Foundation and the Bureau of Labor Statistics, Department of Labor.

Table 37. Natural scientists and engineers in R&D, 1960-70

Year	*R&D scientists as percent of total*			*Relative change (1960=100)*		
	Total U.S.	*Industry*	*Universities and colleges*	*Total U.S.*	*Industry*	*Universities and colleges*
1960	35.0	34.7	42.3	100.0	100.0	100.0
1961	35.6	35.2	42.8	106.1	105.2	107.8
1962	36.5	36.3	42.2	114.5	113.0	113.6
1963	37.1	37.1	41.9	123.2	121.7	122.0
1964	37.5	37.1	39.5	129.0	124.5	128.6
1965	37.5	37.2	38.4	132.9	127.6	132.7
1966	37.1	36.8	36.8	136.3	131.1	135.0
1967	37.5	36.8	39.7	143.5	136.2	158.6
1968	36.2	36.1	36.6	143.2	137.0	154.9
1969	35.0	35.2	35.7	142.2	137.5	150.4
1970	33.6	33.5	33.2	138.7	131.9	155.8

Source: Estimates prepared [illegible] the National Science Foundation based on data collected by the Foundation and the Bureau of Labor Statistics, Department of Labor.

Table 38. Distribution of non-Ph.D. and Ph.D. scientists and engineers, by activity and broad field, 1970

Field	*Non-Ph.D.'s*			*Ph.D.'s*		
	Total	*R&D*	*Other*	*Total*	*R&D*	*Other*
Total	100.0	31.3	68.7	100.0	52.6	47.4
Physical scientists	100.0	38.9	61.1	100.0	66.5	33.5
Life scientists	100.0	31.7	68.2	100.0	56.7	43.3
Mathematicians	100.0	33.5	66.5	100.0	27.1	72.9
Social scientists	100.0	31.7	68.3	100.0	30.7	69.3
Engineers	100.0	29.7	70.3	100.0	59.1	40.9

Source: Estimates prepared by the National Science Foundation based on data collected by the Foundation and the Bureau of Labor Statistics, Department of Labor.

Table 39. Employment of natural scientists and engineers, by sector, 1960 and 1970

Sector	*Percent distribution*		*Percent increase*
	1960	*1970*	1960-70
Total	100.0	100.0	44.4
Private industry	73.5	69.7	36.8
Federal Government	15.3	15.0	41.8
Universities and colleges	10.4	14.3	98.8
Nonprofit institutions	.8	1.0	88.5

Source: Estimates prepared by the National Science Foundation based on data collected by the Foundation and the Bureau of Labor Statistics, Department of Labor.

Table 40. Public secondary school enrollment in selected science and mathematics courses and total enrollment in grades 9 through 12, 1960-61 and 1969-70

Course	*Estimated enrollment (thousands)*			*Index (1948-49*=100)		
	1948-49	*1960-61*	*1969-70*	*1948-49*	*1960-61*	*1969-70*
Biology	1,062	1,853	3,197	100	175	301
Chemistry	412	745	1,160	100	181	282
Physics	291	402	482	100	138	166
Economics	255	293	844	100	115	331
Sociology	186	289	495	100	155	266
Psychology	47	140	344	100	298	732
Introductory algebra	1,042	1,607	2,627	100	154	252
Introductory geometry	599	960	1,530	100	160	255
Advanced mathematics	609	1,174	1,756	100	193	288
Total enrollment, grades 9-12	5,399	8,219	12,442	100	152	230

Source: National Science Foundation, *Science Resources Studies Highlights*, "Enrollment Increase in Science and Mathematics in Public Secondary Schools, 1948-49 to 1969-70" (NSF 71-30), Oct. 15, 1971.

Table 41. Percent change in majors declared by junior-year students, 1970 to 1971

Major field	*Fall 1970*	*Fall 1971*	*Percent change*
Physics	7,377	6,759	—8.4
Engineering	66,421	61,575	—7.3
Chemistry	13,949	13,646	—2.2
Mathematical sciences	34,800	34,581	—.6
Basic social sciences	156,446	170,388	8.9
"All other" life sciences	50,212	56,896	13.3
"Other" physical sciences	8,302	9,556	15.1
Preprofessional life sciences	11,303	14,326	26.7
Applied social sciences	16,375	23,552	43.8

Source: ACE Higher Education Panel, *Survey of Enrollment of Junior-Year Students (Fall 1970 and Fall 1971).*

Table 42. Percent distribution of full-time graduate students in doctorate departments, by area of science and type of support, 1967-71[1]

Type of major support[2]	*All areas*	*Engineering*	*Physical sciences*	*Mathematical sciences*	*Life sciences*	*Psychology*	*Social sciences*
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Fellowships and traineeships:							
1967	32.4	31.2	27.3	26.0	35.9	42.3	36.5
1968	32.1	29.7	26.4	26.6	36.7	41.9	36.2
1969	29.7	26.2	23.4	23.7	35.7	41.6	33.4
1970	27.6	23.6	20.5	20.6	33.0	40.6	32.6
1971	25.4	22.0	18.5	18.8	30.2	35.0	29.3
Research assistantships:							
1967	22.9	29.0	31.4	9.3	25.4	16.6	11.0
1968	22.1	29.7	30.3	8.5	24.0	15.1	10.5
1969	21.6	29.3	31.6	9.1	22.2	14.5	9.5
1970	21.7	30.0	31.3	9.6	22.2	14.4	9.5
1971	20.9	29.4	30.1	9.1	22.5	13.6	9.4
Teaching assistantships:							
1967	23.0	12.7	31.7	40.5	21.4	18.7	18.6
1968	23.5	13.2	32.9	41.8	21.6	19.1	18.4
1969	24.0	13.8	33.8	42.3	22.8	19.3	18.9
1970	25.2	14.0	36.5	46.2	23.5	20.0	19.6
1971	24.7	14.1	37.4	44.1	23.0	20.4	19.5
Other types of support[3]:							
1967	21.7	27.1	9.6	24.2	17.3	22.5	33.9
1968	22.4	27.4	10.5	23.0	17.7	24.0	34.9
1969	24.7	30.7	11.2	24.9	19.3	24.6	38.2
1970	25.5	32.4	11.3	23.5	21.3	25.1	38.3
1971	29.0	34.5	14.0	28.1	24.2	31.0	41.8

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[1] Based on data submitted by 2,236 doctorate departments submitting traineeship applications in each of the years 1967-70 and 2,990 doctorate departments reporting for 1971.

[2] Major support is defined as a total stipend of $1,200 or more, exclusive of tuition, during an academic year.

[3] Includes principally family or self-support.

Source: Special tabulations from National [illegible] Foundation surveys of graduate student support.

Table 43. Distribution of full-time graduate students in science and engineering, by source of support, 1969-71

Type of major support	*1969*	*1970*	*1971*
Total full-time students	131,923	131,902	129,939
U.S. Government	48,373	45,640	41,263
Institutional support	47,415	48,915	48,298
Self-support	24,123	25,155	28,801
Other sources	11,994	12,192	11,577
Fellowships and traineeships	38,972	36,453	32,988
U.S. Government	26,671	24,070	20,959
Institutional support	6,777	6,740	6,628
Self-support	N.A.	N.A.	N.A.
Other sources	5,524	5,643	5,401
Research assistantships	28,506	28,500	27,249
U.S. Government	18,641	18,451	17,519
Institutional support	7,700	8,034	7,588
Self-support	—0—	—0—	—0—
Other sources	2,165	2,015	2,142
Teaching assistantships	31,221	32,616	32,335
U.S. Government	295	336	384
Institutional support	30,790	32,015	31,729
Self-support	—0—	—0—	—0—
Other sources	136	265	222

Source: Special tabulations from National Science Foundation surveys of graduate student support.

Table 44a. Bachelor's and first-professional degrees in science and engineering, 1959-60 to 1970-71

Field of science	*1959-60*	*1960-61*	*1961-62*	*1962-63*	*1963-64*	*1964-65*	*1965-66*	*1966-67*	*1967-68*	*1968-69*	*1969-70*	*1970-71*
All sciences and engineering	120,937	121,660	127,469	135,964	153,361	164,936	173,471	187,849	212,174	244,519	264,122	271,176
Physical sciences	16,057	15,500	15,894	16,276	17,527	17,916	17,186	17,794	19,442	21,591	21,551	21,549
Engineering	37,808	35,866	34,735	33,458	35,226	36,795	35,815	36,188	37,614	41,553	44,772	45,387
Mathematical sciences	11,437	13,127	14,610	16,128	18,677	19,668	20,182	21,530	24,084	28,263	29,109	27,306
Life sciences	24,141	23,900	25,200	27,801	31,611	34,842	36,964	39,408	43,260	48,713	52,129	52,640
Social sciences	31,494	33,267	37,030	42,308	50,320	55,715	63,424	72,929	87,774	104,399	116,561	124,284

Source: U.S. Office of Education, *Earned Degrees Conferred*, annual series.

Table 44b. Bachelor's and first-professional degrees in science and engineering as a percent of all bachelor's and first-professional degrees, 1959-60 to 1970-71

Field of science	*1959-60*	*1960-61*	*1961-62*	*1962-63*	*1963-64*	*1964-65*	*1965-66*	*1966-67*	*1967-68*	*1968-69*	*1969-70*	*1970-71*
All sciences and engineering	30.6	30.3	30.3	30.2	30.5	30.6	31.2	31.6	31.6	31.8	31.7	30.7
Physical sciences	4.1	3.9	3.8	3.6	3.5	3.3	3.1	3.0	2.9	2.8	2.6	2.4
Engineering	9.6	8.9	8.3	7.4	7.0	6.8	6.4	6.1	5.6	5.4	5.4	5.1
Mathematical sciences	2.9	3.3	3.5	3.6	3.7	3.6	3.6	3.6	3.6	3.7	3.5	3.1
Life sciences	6.1	5.9	6.0	6.2	6.3	6.5	6.6	6.6	6.4	6.3	6.3	6.0
Social sciences	8.0	8.3	8.8	9.4	10.0	10.3	11.4	12.3	13.1	13.6	14.0	14.1

Source: U. S. Office of Education, *Earned Degrees Conferred*, annual series.

Table 45a. Master's degrees in science and engineering, 1959-60 to 1970-71

Field of science	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
All sciences and engineering . .	20,012	22,786	25,146	27,367	30,271	33,835	38,083	41,800	45,425	48,425	49,318	50,624
Physical sciences . . .	3,387	3,799	3,929	4,132	4,567	4,918	4,992	5,412	5,508	5,911	5,948	6,386
Engineering	7,159	8,178	8,909	9,635	10,827	12,056	13,678	13,885	15,188	15,243	15,597	16,347
Mathematical sciences	1,765	2,238	2,680	3,323	3,603	4,294	5,610	5,733	6,081	6,735	7,107	6,789
Life sciences	3,751	4,085	4,672	4,718	5,357	5,978	6,666	7,465	8,315	8,809	8,590	9,738
Social sciences	3,950	4,486	4,956	5,559	5,917	6,589	7,737	9,305	10,333	11,727	12,076	12,364

Source: U.S. Office of Education, *Earned Degrees Conferred*, annual series.

Table 45b. Master's degrees in science and engineering as a percent of all master's degrees, 1959-60 to 1970-71

Field of science	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
All sciences and engineering . .	26.9	29.1	29.6	29.9	29.9	30.2	27.1	26.5	25.6	24.9	23.6	21.9
Physical sciences . . .	4.5	4.9	4.6	4.5	4.5	4.4	3.5	3.4	3.1	3.0	2.8	2.8
Engineering	9.6	10.4	10.5	10.5	10.7	10.7	9.7	8.8	8.6	7.8	7.4	7.1
Mathematical sciences	2.4	2.9	3.2	3.6	3.6	3.8	3.6	3.6	3.4	3.5	3.4	2.9
Life sciences	5.0	5.2	5.5	5.2	5.3	5.3	4.7	4.7	4.7	4.5	4.1	3.8
Social sciences	5.3	5.7	5.8	6.1	5.9	5.9	5.5	5.9	5.8	6.0	5.8	5.3

Source: U.S. Office of Education, *Earned Degrees Conferred*, annual series.

Table 46a. Doctor's degrees in science and engineering, 1959-60 to 1970-71

Field of science	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
All sciences and engineering . .	6,056	6,531	7,249	8,055	9,025	10,252	11,298	12,759	14,128	15,839	17,639	18,466
Physical sciences . . .	1,838	1,991	2,122	2,380	2,455	2,829	3,045	3,462	3,593	3,859	4,313	4,391
Engineering	786	943	1,207	1,378	1,693	2,124	2,304	2,614	2,932	3,377	3,681	3,654
Mathematical sciences	303	344	396	490	596	688	801	870	983	1,161	1,343	1,327
Life sciences	1,647	1,646	1,804	1,908	2,181	2,474	2,696	2,900	3,445	3,779	4,131	4,746
Social sciences	1,482	1,607	1,720	1,899	2,100	2,137	2,452	2,913	3,175	3,663	4,171	4,348

Source: U.S. Office of Education, *Earned Degrees Conferred*, annual series.

Table 46b. Doctor's degrees in science and engineering as a percent of all doctor's degrees, 1959-60 to 1970-71

Field of science	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71
All sciences and engineering . .	61.6	61.8	62.4	62.8	62.3	62.3	61.9	61.9	61.2	60.5	59.0	57.5
Physical sciences . . .	18.7	18.8	18.3	18.6	16.9	17.2	16.7	16.8	15.6	14.7	14.4	13.7
Engineering	8.0	8.9	10.4	10.7	11.7	12.9	12.6	12.7	12.7	12.9	12.3	11.4
Mathematical sciences	3.1	3.3	3.4	3.8	4.1	4.2	4.4	4.2	4.3	4.4	4.5	4.1
Life sciences	16.8	15.6	15.5	14.9	15.1	15.0	14.8	14.1	14.9	14.4	13.8	14.8
Social sciences	15.1	15.2	14.8	14.8	14.5	13.0	13.4	14.1	13.7	14.0	14.0	13.5

Source: U.S. Office of Education, *Earned Degrees Conferred*, annual series.

Table 47. Geographic origins, by high school graduation, of Ph.D.'s in science and technology, 1970

Region, division, and State	*Population (thousands)*		*Ph.D.'s in science and engineering by State of high school graduation*	
	April 1, 1960 (census)	*April 1, 1970 (census)*	*FY 1960*	*FY 1970*
United States, Total	179,323	203,166	5,128	14,272
NORTHEAST				
New England	10,509	11,842	436	968
Maine	969	992	29	39
New Hampshire	607	738	33	67
Vermont	390	444	10	23
Massachusetts	5,149	5,689	240	543
Rhode Island	859	947	35	73
Connecticut	2,535	3,032	89	223
Middle Atlantic	34,168	37,153	1,499	3,641
New York	16,782	18,191	951	2,058
New Jersey	6,067	7,168	231	586
Pennsylvania	11,319	11,794	317	997
NORTH CENTRAL				
East North Central	36,225	40,252	1,066	2,862
Ohio	9,706	10,652	253	730
Indiana	4,662	5,194	102	320
Illinois	10,081	11,114	403	915
Michigan	7,823	8,875	168	519
Wisconsin	3,952	4,418	150	378
West North Central	15,394	16,319	493	1,415
Minnesota	3,414	3,805	115	301
Iowa	2,758	2,824	98	293
Missouri	4,320	4,677	118	349
North Dakota	632	618	16	49
South Dakota	681	666	23	70
Nebraska	1,411	1,483	50	123
Kansas	2,179	2,247	73	230
SOUTH				
South Atlantic	25,972	30,671	402	1,399
Delaware	446	548	10	36
Maryland	3,101	3,922	59	243
District of Columbia	764	757	36	77
Virginia	3,967	4,148	74	261
West Virginia	1,860	1,744	49	111
North Carolina	4,556	5,082	43	186
South Carolina	2,383	2,591	27	79
Georgia	3,943	4,590	42	156
Florida	4,952	6,789	62	250
East South Central	12,050	12,803	176	602
Kentucky	3,038	3,219	50	143
Tennessee	3,567	3,924	46	205
Alabama	3,267	3,444	46	145
Mississippi	2,178	2,217	34	109
West South Central	16,951	19,321	304	1,149
Arkansas	1,786	1,923	42	81
Louisiana	3,257	3,641	43	203
Oklahoma	2,328	2,559	67	219
Texas	9,510	11,197	152	646

Table 47—Continued

WEST				
Mountain	6,855	8,282	247	714
Montana	675	694	28	71
Idaho	667	713	38	81
Wyoming	330	322	20	38
Colorado	1,754	2,207	55	180
New Mexico	951	1,016	16	88
Arizona	1,302	1,771	28	79
Utah	891	1,059	59	158
Nevada	285	489	3	19
Pacific	21,198	26,523	505	1,522
Washington	2,853	3,409	84	252
Oregon	1,769	2,091	57	147
California	15,717	19,953	344	1,078
Alaska	226	300	2	7
Hawaii	633	769	18	38

Source: Department of Commerce, Bureau of the Census, decennial census reports and National Research Council, *Doctorate Recipients from U.S. Universities*, annual series.

Table 48. Unemployment rates, 1963-72

Year (averages)	*All workers*	*Professional and scientific workers*	*Scientists*	*Engineers*
1963	5.7	1.9	—	1.2
1964	5.1	1.8	—	1.5
1965	4.6	1.5	—	1.1
1966	3.9	1.3	.4	.7
1967	3.7	1.3	—	.6
1968	3.6	1.2	.9	.7
1969	3.5	1.3	—	.8
1970	5.0	2.0	1.6	2.2
1971	6.0	3.0	2.6	2.9
1972	5.6	2.4	—	2.0
1st quarter	6.3	2.3	—	2.8
2nd quarter	5.6	2.3	—	2.0
3rd quarter	5.6	2.9	—	1.8
4th quarter	4.9	2.1	—	1.2

Sources: Department of Labor, Bureau of Labor Statistics, periodic reports on labor force and National Science Foundation, *Unemployment Rates and Employment Characteristics for Scientists and Engineers, 1971* (NSF 72-307).

Table 49a. Unemployment rates for scientists and engineers, by age group, 1971

Age group	Scientists	Engineers
	Percent	
Total	2.6	3.0
24 and under	5.5	5.5
25-29	5.3	3.3
30-34	2.9	2.2
35-39	2.1	2.2
40-44	1.8	2.7
45-49	2.1	2.8
50-54	2.0	3.3
55-59	1.8	4.1
60-64	1.8	4.2
65 and over	2.3	3.4

Source: National Science Foundation, *Unemployment Rates and Employment Characteristics for Scientists and Engineers, 1971* (NSF 72-307).

Table 49b. Unemployment rates for scientists and engineers, by highest degree, 1971

Highest degree	Scientists	Engineers
	Percent	
Total	2.6	3.0
Doctorate	1.4	1.9
Master's	3.7	3.2
Bachelor's	3.5	2.8
Less than bachelor's	4.1	4.4

Source: National Science Foundation, *Unemployment Rates and Employment Characteristics for Scientists and Engineers, 1971* (NSF 72-307).

Table 50. Percent of new science and engineering Ph.D.'s planning to engage in "further education or training" or "postdoctoral study," by field, fiscal years 1960-71[1]

	Fiscal year of doctorate											
Field of science	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
All science and engineering	10.4	13.1	14.4	14.9	14.6	15.7	15.9	15.7	15.4	21.0	22.2	23.0
Physical sciences	13.3	18.7	20.8	21.5	21.9	22.8	24.6	24.8	22.8	33.6	35.5	38.6
Mathematics	7.6	7.2	12.1	8.5	7.0	6.6	6.2	6.9	4.5	8.7	7.9	7.1
Engineering	3.5	3.0	4.1	6.0	5.7	6.0	5.4	4.4	4.6	7.1	8.1	11.0
Life sciences	16.0	21.1	22.4	23.0	23.6	25.7	26.0	26.6	28.4	35.7	38.2	37.0
Social sciences	5.0	5.6	6.1	6.3	5.8	7.0	7.0	6.6	6.1	8.1	8.1	7.7

[1] Due to a change in definition, 1969 through 1971 data are not strictly comparable with earlier years.

Source: National Research Council, *Doctorate Recipients from U.S. Universities*, annual series.

Table 51. Median number of years from baccalaureate to doctorate of doctorate recipients in science and engineering, by field, fiscal years 1960-71

	Fiscal year of doctorate											
Field of science	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Physical sciences	6.4	6.5	6.4	6.3	6.2	6.3	6.1	6.0	6.1	6.1	6.1	6.2
Mathematics	7.2	7.5	7.1	6.8	6.1	6.1	5.8	6.1	5.9	5.9	6.0	6.2
Engineering	7.4	7.1	7.1	6.9	7.0	7.0	7.0	7.2	7.1	7.0	6.9	7.2
Life sciences	8.0	7.8	7.7	7.5	7.3	7.3	7.3	7.1	7.1	6.8	6.5	6.8
Social sciences	8.8	9.2	9.1	8.6	8.3	8.0	7.8	7.8	7.8	7.5	7.4	7.2

Source: National Research Council, *Doctorate Recipients from U.S. Universities*, annual series.

Table 52. Number of institutions of higher education by highest degree awarded in science and engineering, 1960-61 to 1970-71

	Number of institutions granting—		
Year	*Bachelor's degrees*	*Master's degrees*	*Doctorate degrees*
1960-61	748	189	153
1961-62	745	212	155
1962-63	754	209	162
1963-64	757	218	172
1964-65	754	233	178
1965-66	745	246	187
1966-67	752	271	194
1967-68	746	281	196
1968-69	756	292	206
1969-70	764	295	220
1970-71	NA	NA	229

Source: Special tabulation by National Science Foundation based on data provided by the U. S. Office of Education.

Table 53a. Scientists and engineers[1] employed in universities and colleges, 1965-71
[In thousands]

	Number employed in institutions granting—		
Year	*Bachelor's degrees*	*Master's degrees*	*Doctorate degrees*
1965 ..	20.3	18.5	103.5
1967 ..	20.9	22.2	125.2
1969 ..	22.4	30.4	140.2
1971 ..	24.3	31.0	157.3

[1] Full-time equivalents.

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges*, biennial series.

Table 53b. Concentration of scientists and engineers[1] employed in universities and colleges, 1965-71

	Percent employed in institutions granting—		
Year	*Bachelor's degrees*	*Master's degrees*	*Doctorate degrees*
1965 ..	14	13	73
1967 ..	12	13	74
1969 ..	12	16	73
1971 ..	11	15	74

[1] Full-time equivalents.

Source: National Science Foundation, *Resources for Scientific Activities at Universities and Colleges*, biennial series.

Table 54. Science and engineering degrees awarded at baccalaureate, master's, and doctorate-granting institutions, 1963-64 to 1969-70

Type of institution and level of degree	*1963-64*	*1965-66*	*1968-69*	*1969-70*
Doctorate-granting:				
Bachelor's degrees	79,680	90,230	124,191	139,768
Master's degrees	25,582	32,450	39,398	40,107
Ph.D. degrees	8,928	11,298	15,839	17,639
Master's and bachelor's:				
Bachelor's degrees[1]	34,434	41,962	67,424	69,841
Bachelor's degrees[2]	39,216	41,279	52,904	54,513
Master's degrees	4,320	5,633	9,027	9,211

[1] Master's institutions.

[2] Baccalaureate institutions.

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 55. Number of Ph.D. degrees awarded in science and engineering, by selected groups of institutions,[1] 1962-63 to 1970-71

Groups of institutions	*1962-63*	*1965-66*	*1969-70*	*1970-71*
All institutions	7,947	11,398	17,639	18,407
First 20 institutions	4,040	5,076	7,024	7,125
Second 20 institutions	1,650	2,365	3,456	3,645
Remaining institutions	2,284	3,857	7,159	7,697

[1] Ranked in terms of doctorates awarded in each year.

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 56a. Total full-time graduate students in science and engineering enrolled in selected groups of doctorate-granting institutions, 1962-63 to 1970-71

Groups of institutions	*1962-63*	*1965-66*	*1969-70*	*1970-71*
All institutions	69,622	105,190	135,123	138,822
First 20 institutions	29,825	43,185	46,465	45,782
Second 20 institutions	13,792	18,820	24,481	24,789
Remaining institutions	26,005	43,185	64,177	68,251

[1] Ranked in terms of doctorates awarded in each year.

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 56b. First-year, full-time graduate students in science and engineering enrolled in selected groups of doctorate-granting institutions,[1] 1962-63 to 1970-71

Groups of institutions	*1962-63*	*1965-66*	*1969-70*	*1970-71*
All institutions	30,895	47,259	56,858	60,358
First 20 institutions	11,319	17,150	18,039	17,636
Second 20 institutions	5,598	7,784	9,718	10,379
Remaining institutions	13,978	22,325	29,101	32,343

[1] Ranked in terms of doctorates awarded in each year.

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 57a. Number of institutions granting Ph.D. degrees in science and engineering, by control, selected years, 1962-63 to 1970-71

Academic year	*Total*	*Public*	*Private*
1962-63	162	93	69
1963-64	172	96	76
1965-66	187	107	80
1966-67	194	111	83
1969-70	222	129	93
1970-71	229	135	94

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 57b. Number of Ph.D. degrees awarded in science and engineering, by control of institution, 1963-64 to 1970-71

Academic year	*Total*	*Public*	*Private*
1963-64	8,928	5,282	3,646
1965-66	11,298	6,887	4,411
1966-67	12,759	7,785	4,974
1967-68	14,128	8,851	5,277
1968-69	15,839	10,114	5,725
1969-70	17,639	11,471	6,168
1970-71	18,466	12,261	6,205

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 58. Graduate enrollment by control of institution, selected years
[Thousands]

Control of institution	*Total graduate enrollment*			*First-year graduate enrollment*		
	1965	*1969*	*1970*	*1965*	*1969*	*1970*
Total, all institutions	226	264	266	109	112	115
Public institutions	156	186	192	76	78	84
Private institutions	70	78	74	33	34	31

Source: Special tabulation by the National Science Foundation based on data supplied by the U.S. Office of Education.

Table 59. Proportion of NSF and NIH[1] research project grant funds allocated for permanent laboratory equipment, fiscal years 1966-71
[Percent]

Fiscal year	*NSF*	*NIH*
1966	11.2	11.7
1967	8.6	11.8
1968	7.5	9.5
1969	7.0	7.5
1970	6.0	5.9
1971	6.1	NA

---

[1] Includes National Institute of General Medical Sciences and National Heart and Lung Institute.

Source: National Science Foundation from unpublished data.

Table 60. Percent distribution of NSF research project support, by type of expenditure, fiscal years 1964-72

Type of expenditures	Fiscal year 1964	1965	1966	1967	1968	1969	1970	1971	1972
Total (millions of dollars)	$113	$120	$157	$168	$171	$176	$162	$175	$242
	Percent distribution								
Total, salaries and wages	54	54	52	52	53	52	52	51	52
Research associates/ assistants salaries and wages	22	23	23	22	22	22	21	19	21
Equipment[1]	20	19	18	16	15	15	13	14	13
Indirect costs	16	15	17	20	21	22	22	22	22
Other costs	10	12	13	12	12	11	12	13	12

[1] Permanent and expendable equipment.

Source: National Science Foundation from unpublished data.

Table 61a. Federal obligations for R&D plant, fiscal years 1963-71
[Dollars in millions]

Fiscal year	Current dollars	Constant 1961 dollars[1]
1963	$105.9	$99.8
1964	100.8	92.6
1965	126.2	112.3
1966	114.8	98.8
1967	111.3	91.3
1968	96.1	75.7
1969	54.5	40.9
1970	44.8	31.9
1971	29.9	20.1

[1] Based on academic R&D price deflator.

Source: National Science Foundation, *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, Fiscal year 1971* (NSF 73-300).

Table 61b. Federal obligations for academic R&D plant as a percent of Federal obligations for academic science, fiscal years 1963-71

Year	Total Federal obligations for academic science (dollars in millions)	Percent share for academic R&D plant
1963	$1,328.5	8.0
1964	1,528.6	6.6
1965	1,816.2	7.0
1966	2,163.5	5.3
1967	2,323.8	4.8
1968	2,349.8	4.1
1969	2,361.4	2.3
1970	2,167.9	2.1
1971	2,335.9	1.3

Source: National Science Foundation, *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, Fiscal Year 1971* (NSF 73-300).

Table 62a. Federal obligations for intramural R&D performance, fiscal years 1961-72

[Dollars in millions]

Fiscal year	Current dollars	Constant 1958 dollars[1]
1961	$1,874	$1,800
1962	2,098	1,994
1963	2,279	2,142
1964	2,838	2,630
1965	3,093	2,814
1966	3,222	2,874
1967	3,395	2,934
1968	3,495	2,916
1969	3,498	2,798
1970	3,876	2,941
1971	4,166	3,006
1972 (est.)	4,500	3,136

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

Table 62b. Federal intramural R&D funds as a share of national and Federal R&D totals, 1960-72

[Dollars in millions]

Year	Federal R&D	National R&D	Federal intramural R&D as a percent of:	
			Federal R&D	National R&D
1960	$ 7,552	$13,730	23	13
1961	9,059	14,552	21	13
1962	10,290	15,665	20	13
1963	12,495	17,371	18	13
1964	14,225	19,214	20	15
1965	14,614	20,439	21	15
1966	15,320	22,266	21	14
1967	16,529	23,612	21	14
1968	15,921	25,119	22	14
1969	15,637	26,176	22	13
1970	15,330	26,695	25	15
1971	15,550	27,320	27	15
1972 (est.)	16,821	28,940	27	16

Source: National Science Foundation, *National Patterns of R&D Resources, 1953-73* (NSF 73-303) and *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

Table 63. Federal obligations for intramural R&D performance, by agency, fiscal years 1961-72

[Dollars in millions]

Agency	*1961*	*1962*	*1963*	*1964*	*1965*	*1966*	*1967*	*1968*	*1969*	*1970*	*1971*	*1972 (est.)*
Total	$1,874	$2,098	$2,279	$2,838	$3,093	$3,222	$3,396	$3,493	$3,498	$3,876	$4,166	$4,500
Department of Defense	1,331	1,468	1,435	1,615	1,647	1,720	1,890	1,951	1,867	1,996	2,201	2,418
National Aeronautics and Space Administration	179	213	381	706	863	872	813	791	821	988	909	912
Department of Health, Education, and Welfare	97	121	132	150	161	182	204	222	243	247	298	334
Department of Agriculture	104	109	118	130	153	164	175	182	190	208	227	251
Department of the Interior	62	68	72	73	82	94	109	116	123	100	112	127
Department of Commerce	29	32	39	43	46	42	49	55	58	88	92	109
Department of Transportation	—	—	—	—	—	41	45	52	54	64	101	111
National Science Foundation	5	7	12	13	14	13	12	12	15	14	19	19
Atomic Energy Commission	19	19	14	22	31	20	15	17	17	18	17	15
All other	48	62	77	87	97	74	84	96	110	153	190	212

Source: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

Table 64. Federal obligations for intramural performance, by character of work, fiscal years 1961-72

[Dollars in millions]

Year	*Current dollars*				*Constant 1958 dollars*[1]			
		Research				*Research*		
	R&D	*Basic*	*Applied*	*Development*	*R&D*	*Basic*	*Applied*	*Development*
1961	$1,874	$206	$ 634	$1,034	$1,800	$198	$609	$ 993
1962	2,098	251	702	1,145	1,994	239	667	1,088
1963	2,279	299	730	1,250	2,142	281	686	1,175
1964	2,838	364	928	1,546	2,630	337	860	1,433
1965	3,093	424	1,030	1,639	2,814	386	937	1,491
1966	3,222	449	1,045	1,728	2,874	401	932	1,541
1967	3,395	478	1,095	1,822	2,934	413	946	1,575
1968	3,493	512	1,199	1,782	2,916	427	1,001	1,487
1969	3,498	577	1,195	1,726	2,798	462	956	1,381
1970	3,876	658	1,375	1,343	2,941	499	1,043	1,398
1971	4,166	535	1,499	2,132	3,006	386	1,082	1,538
1972 (est.)	4,500	578	1,594	2,337	3,136	402	1,108	1,625

[1] GNP price deflator was used to convert current to constant dollars.

Source: National Science Foundation, *Federal Funds for Research, Development, and Other Scientific Activities*, Vol. XXI (NSF 72-317).

Table 65. Percent distribution of industrial R&D scientists and engineers,[1] by company size, 1957-71

Year	Total R&D scientists and engineers	Companies with— Less than 1,000 employees	1,000-4,999 employees	5,000 or more employees
1957 ...	229,400	19.5	9.8	70.7
1958 ...	243,800	20.0	9.8	70.1
1959 ...	268,400	14.8	10.1	75.1
1960 ...	292,000	13.4	10.2	76.4
1961 ...	312,100	13.5	10.9	75.6
1962 ...	312,000	11.7	11.3	77.0
1963 ...	327,300	10.4	10.7	78.9
1964 ...	340,200	9.6	10.1	80.3
1965 ...	343,600	9.4	9.3	81.2
1966 ...	353,200	8.5	8.5	83.0
1967 ...	367,200	7.5	8.3	84.2
1968 ...	376,700	7.2	7.9	84.9
1969 ...	387,100	7.0	7.3	85.7
1970 ...	384,100	6.5	8.2	85.3
1971 ...	359,300	6.2	8.7	85.1

[1] Full-time equivalents.

Source: National Science Foundation, *Research and Development in Industry, 1970* (NSF 72-309).

Table 66. R&D intensiveness of U.S. industry, 1960-70

Year	Funds for R&D performance (millions of dollars)	R&D as percent of net sales	R&D scientists and engineers[1] Number	Per 1,000 employees
1960	$10,509	4.2	292,000	25
1961	10.908	4.3	312,100	28
1962	11,464	4.3	312,000	28
1963	12,630	4.5	327,300	28
1964	13,512	4.6	340,200	30
1965	14,185	4.3	343,600	30
1966	15,548	4.2	353,200	27
1967	16,385	4.2	367,200	27
1968	17,429	4.0	376,700	26
1969	18,318	4.0	387,100	26
1970	17,858	3.8	384,100	24

[1] Full-time equivalents.

Source: National Science Foundation, *Research and Development in Industry, 1970* (NSF 72-309).

Table 67. R&D intensiveness of groups of manufacturing industries, 1960-70

	Group I		*Group II*		*Group III*	
	R&D funds (in millions)					
Year	*Total*	*Percent of net sales*	*Total*	*Percent of net sales*	*Total*	*Percent of net sales*
1960	$ 8,304	10.0	$1,534	1.8	$385	0.6
1961	8,610	9.6	1,597	2.0	401	.6
1962	9,079	9.6	1,692	1.9	395	.6
1963	10,059	10.2	1,816	2.0	423	.6
1964	10,682	10.7	2,003	2.0	451	.6
1965	11,167	10.4	2,085	1.8	491	.6
1966	12,228	9.5	2,229	1.8	537	.5
1967	12,886	8.8	2,692	1.9	561	.5
1968	13,579	8.2	2,956	1.9	591	.6
1969	14,192	8.3	3,108	1.9	648	.6
1970	13,731	8.0	2,950	2.0	668	.6
	R&D scientists and engineers					
	Number	*Per 1,000 employees*	*Number*	*Per 1,000 employees*	*Number*	*Per 1,000 employees*
1960	222,700	48.2	39,700	15.2	15,700	5.6
1961	238,800	50.4	45,800	17.6	16,300	5.2
1962	239,500	48.2	46,600	17.2	14,600	5.6
1963	255,600	51.6	46,400	16.6	14,300	5.0
1964	265,100	54.2	48,900	16.6	14,700	5.2
1965	266,200	53.6	50,300	16.4	15,400	5.2
1966	272,600	47.4	51,000	16.0	15,800	5.0
1967	282,700	45.6	52,000	16.6	16,700	5.0
1968	290,000	44.4	52,300	15.8	17,500	5.2
1969	296,500	42.6	55,000	16.2	18,300	5.6
1970	291,300	42.0	55,200	16.0	18,900	5.2

Source: National Science Foundation, *Research and Development in Industry, 1970,* (NSF 72-309).

Table 68. R&D intensiveness in manufacturing industries, by company size, 1967-70

	1967		*1970*	
	Funds for R&D			
Size of company (number of employees)	*Amount (millions of dollars)*	*Percent of net sales*	*Amount (millions of dollars)*	*Percent of net sales*
Less than 1,000	$ 687	1.7	N.A.	N.A.
1,000-4,999	1,017	1.7	N.A.	N.A.
5,000-9,999	892	2.1	$ 1,077	2.2
10,000 or more	13,790	5.2	14,890	4.5
	R&D scientists and engineers			
	Number	*Per 1,000 employees*	*Number*	*Per 1,000 employees*
Less than 1,000	27,400	28	N.A.	N.A.
1,000-4,999	30,500	16	N.A.	N.A.
5,000-9,999	24,000	16	28,500	18
10,000 or more	285,300	30	299,100	26

Source: National Science Foundation, *Research and Development in Industry, 1970,* (NSF 72-309).

Appendix B—Delphi Panelists

Delphi Panelists

Philip H. Abelson
President
Carnegie Institution of Washington

William C. Ackermann
Chief
Illinois State Water Survey

Robert M. Adams
Vice President, Research and Development
3M Center

Richard A. Askey
Department of Mathematics
University of Wisconsin

Eric Baer
Head, Division of Macromolecular Science
Case Western Reserve University

Malcolm R. Beasley
Division of Engineering and Applied Physics
Harvard University

D. Allan Bromley
Director, Wright Nuclear Structure Laboratory
Yale University

Harvey Brooks
National Science Board
Dean of Engineering and Applied Physics
Harvard University

Arthur M. Bueche
Vice President, Research and Development
General Electric Company

Theodore Cairns
Director, Central Research Department
E. I. Du Pont de Nemours & Company

Melvin Calvin
Laboratory of Chemical Biodynamics
University of California, Berkeley

Richard A. Carpenter
Commission on Natural Resources
National Academy of Sciences
National Research Council

H. E. Carter
Chairman, National Science Board
Coordinator, Interdisciplinary Programs
University of Arizona

David R. Challoner
Assistant Chairman, Department of Medicine
Indiana University Medical Center

Robert A. Charpie
National Science Board
President
Cabot Corporation

Adolth S. Clausi
Vice President, Director of Corporation Research
General Foods, Technical Center

Lloyd M. Cooke
National Science Board
Director of Urban Affairs
Union Carbide Corporation

H. Richard Crane
Physics Department
University of Michigan

John P. Crecine
Director, Institute of Public Policy Studies
University of Michigan

Arnold E. Denton
Vice President, Technical Administration
Campbell Soup Company

Robert H. Dicke
National Science Board
Department of Physics
Princeton University

Harry Eagle
Department of Cell Biology
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